A Study of the Market Potential for an Ultrasonic and Video Imaging System for Quality Assurance of Agricultural Grains and Seeds

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The Ultrasonic and Video Imaging System has been developed by the Iowa State University Seed Science Center. Funding for this study was provided by the ISU Center for Advanced Technology Development.

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ABSTRACT

Ultrasonic scanning and video imaging are two valuable techniques for a variety of seed and grain testing purposes. This study evaluates the market potential of a system being developed by the Iowa State University Seed Science Center, which combines these two techniques to permit precise measurement of seed and grain quality. Emphasis is placed on the Iowa soybean industry's need for a preconfigured Quality Assurance (QA) system, but the study also examines potential use in the nonsoybean agricultural industry. Both hardware and software needs are evaluated according to survey responses from the QA managers of 37 private Iowa firms. In general, both seed and nonseed sectors of the agricultural industry expressed abundant interest in the equipment, although the demand for specific system capabilities varied by sectors within the industry. Most Iowa firms make use of in-house testing facilities, so private testing laboratory demand within Iowa appears negligible.

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Undetected errors remain the sole responsibility of the authors.

A STUDY OF THE MARKET POTENTIAL FOR AN ULTRASONIC AND VIDEO IMAGING SYSTEM FOR QUALITY ASSURANCE OF AGRICULTURAL GRAINS AND SEEDS

Characterization of seed and grain quality ranges from simple visual examination of attributes such as color, physical damage, and cleanliness to more complex procedures of chemically determining oil and protein contents. How and for what purpose the seeds and grains are used in a particular enterprise determines which quality characteristics are pertinent to that enterprise. For instance, a producer of seed material needs to ensure viability and true-to-type performance, while a miller is likely to focus on the potential for starch or oil output. Thus the various sectors of the seed and grain industry have established procedures to test seed and grain samples for specified quality characteristics.

The ISU Seed Science Center is designing automated, computerized equipment that uses a combination of video imaging and ultrasonic technologies to facilitate and enhance testing procedures for seeds and grains. This study was undertaken to assess the market potential of this integrated, computerized Quality Assurance (QA) system.

This QA system consists of a computer and printer unit, a video camera, an ultrasonic device, a seed feeding device, and a seed testing software package. The system maps the image of small objects, measures quality parameters, and compares them with prespecified standards. It is ideally suited for small round seeds such as soybeans but can be extended to test other grains as well as industrial products such as metal nuts and bolts. The system could have a wide range of applications: in research laboratories for precise measurements for scientific and biological research, as a standardization tool in commercial grain handling, and as field equipment in a combine to monitor and control seed damage in harvesting and threshing operations. Such a computerized testing package has a number of advantages over current procedures:

- increased precision,
- high speed,
- less labor intensive,
- reduced subjectivity,
- wider applications,
- adaptability to suit specific work environments, and
- fewer work tools and less work space.

This system can replace current testing, expand the parameters tested, increase the volume tested, increase the number of users, and reduce the cost of testing.

These enhancements may be translated into direct and indirect economic benefits. For instance, automation and the consequent labor savings are direct benefits. Increase in precision and speed of measurement, on the other hand, would enable better management decisions and provide indirect benefits. Adopting new technology will depend most critically on potential economic benefit from such adoption. This study examines the potential of this new ultrasonic and video imaging technology for Quality Assurance programs in seeds and grains. Primary focus is on the Iowa soybean seed industry. However, other possible markets in Iowa agriculture are also examined. Further, an attempt is made to extrapolate the Iowa results to potential U.S. and world use.

Market Potential of the QA System

The general objective of this study is to evaluate the market potential of the agricultural grain and seed quality testing system, ultrasonic and video imaging of agricultural grain and seeds for Quality Assurance (QA system), with emphasis on the Iowa soybean industry.

In keeping with this general objective, this market study was designed to address seven specific objectives:

1. Estimate Iowa soybean industry demand for a preconfigured QA system.

2. Estimate Iowa nonsoybean agricultural industry demand for this preconfigured system. Emphasis was placed on corn, given its importance in Iowa. Further, because of the similarity between soybeans and edible peas and the high quality control requirements in handling and processing of edible peas, the demand in this sector was specifically addressed.

3. Extrapolate the respective national and world demands, using the estimates of Iowa demand.

4. Classify these demands by industry type: seed firms, mills, and commercial laboratories.

5. Estimate research laboratory demand for the system.

6. Provide a summary of hardware and software features the industry would require as either standard or customized.

7. Provide a summary of other concerns, such as substitutability of existing hardware, preference for additional measurements for quality characterization, trade-off between accuracy and time for field versus laboratory testing, portability, and user support of the system.

Sampling and Data Gathering

Following a pilot survey of four seed firms and a number of university staff involved in seed quality testing, a questionnaire was designed to obtain the required information (Appendix A). The ISU Seed Science Center provided an audiovisual package to use during the firm interviews to demonstrate the features of the proposed testing system. The soybean study was based on a sample of Iowa firms listed in the Directory of Iowa Manufacturers under the "soybean" category. Data on seed testing of other grains and seeds were also obtained from these firms. This information was complemented with a 10 percent sample of nonsoybean firms from the same directory to study the nonsoybean agricultural demand for the system, both in the seed and nonseed sectors of the industry (such as millers and elevators).

Three possible methods to examine and determine market demand were considered. First, the firms suggested a fair price for the system. Next, the current cost of seed testing (either in house, or by an outside contractor) was estimated using the firms' operating cost information. Demand for the alternative system was then assessed on the basis of opportunity cost. Third, factors influencing purchase decisions were studied to infer "will or will not purchase" decisions of firms.

Survey Results and Analysis

Sample and Weights

Of the 373 firms listed in the Directory of Iowa Manufacturers under the seed and grain categories (coded 2039 to 2048), 37 firms were selected for this study (Table 1). Since the main emphasis was on soybean seed firms, a disproportionate sampling was adopted, targeting 12 of the 19 soybean seed firms. The other 25 firms were selected from among the other categories based on their likely interest in seed and grain quality testing. The sample proportions were used in the final results projection to appropriately represent their share in the grain and seed industry. That is, if 10 firms were sampled from a category with 25 firms, then each firm received a weight of 2.5.

The QA manager in each firm was contacted and an interview was arranged with those professionals involved in seed and grain testing. Thus, for individual firms with more than one respondent, each response was given equal weight.

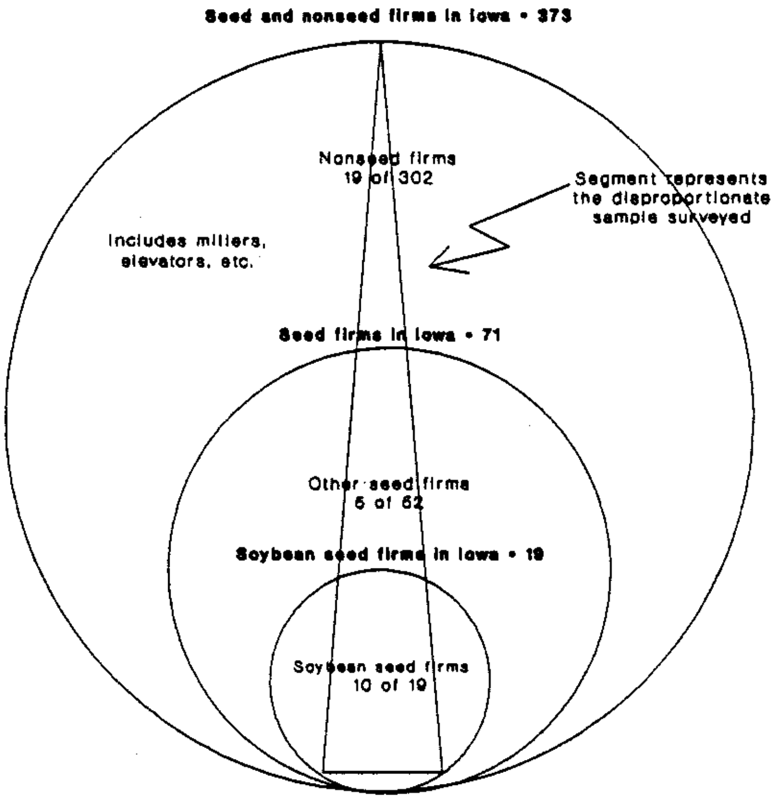
A total of 69 respondents representing 23 firms completed the survey. One firm was categorized as a mill as well as a breakfast or cereal manufacturer (codes 2041 and 2043), so their response was counted twice, once in each category, to retain the validity of the sampling procedure. Of the 12 soybean seed firms targeted, two were unable or declined to respond, resulting in a sample of 10. Similarly, of the six corn seed firms two could not be interviewed, but another firm not originally selected volunteered, resulting in a sample of five representing 52 firms.[1] Ten "other" firms, mainly millers and pet food manufacturers, declared that the proposed equipment would not interest them for various reasons. They represent the industry sector that does not anticipate using the QA system so they were counted as part of the sample. That is, 19 firms represented the 302 firms constituting the nonseed industry in Iowa; of these 19, 10 responded negatively to the QA system. Figure 1 illustrates the target population of firms and the study sample.

Table 1. Summary of Iowa firms involved in seed or grain handling

Category	Code	Employment Category[a]							Total	Target Sample	Resp.	No. Resp.	N/R	No Interest
		A	B	C	D	E	F	G						
Soybean and other processed seeds	2039	10	7	2					19	12	10	22	2	
Hybrid corn seeds	2040	35	14	2	1				52	6	5	19	2	
Flour, grain mill products	2041	2	1	1	1			1	6	3	1	3		2
Cereal breakfast foods	2043				1	1	1	1	4	2	1	3		1
Blended and prepared flour	2045					1			1	1				1
Wet corn milling	2046		1		3	3	1		8	4	2	11		2
Dog, cat and pet food	2047	14	5	2	2	2	1		26	3				3
Not listed elsewhere	2048	192	52	9	4				257	6	5	11		1
TOTAL		253	80	16	12	7	3	2	373	37	24	69	4	10

SOURCE: *Directory of Iowa Manufacturers, 1983-84*

[a]A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1000, G > 1000. This refers to number of employees at specified site.



Note: Firm type distribution in Iowa, and in sample:

	Total	Sample
Soybean seed firms	19	10
Other seed firms	52	5
All seed firms	71	15
Nonseed firms(millers, etc.,)	302	19
All firms	373	34
Firms not interested in QA System (all were nonseed firms)		10
Number surveyed		24

Figure 1. Iowa firms handling seeds and grains

Sample Firm Profile

Each of the firms sampled was identified as either a single branch firm, main office of a multiple branch firm, or a branch office of a multiple branch firm. The distribution among the seed and nonseed firm categories is listed in Table 2 and it is apparent that a large proportion of firms are multibranch businesses.

As for the type and volume of seeds or grain handled by the firms (Table 3), five handled soybeans exclusively, while two handled only corn. The other seven were involved in both soybean and corn seed processing. For the seed industry, annual volumes of soybeans handled ranged from 0.005 to 8.3 million bushels, while the range for corn was 0.002 to 10 million bushels. Nonseed firms, such as elevators or millers, generally handled much lower volumes of soybeans (.125 to .75 million bushels) but higher volumes of corn (.6 to 22 million bushels).

Other crops reported in the seed as well as nonseed industries are summarized in Table 4. Wheat, oats, sorghum, sunflower, alfalfa, and rapeseed were reported. The volumes of these crops were in general very low, except for oats in the milling industry.

The seed and grain handling activities within the industry are broadly divided into several categories such as growing, conditioning, testing, and grading, as shown in the left column of Table 5. Each of the firms was asked to categorize its activities with regard to primary or secondary tasks. A secondary task was defined as an operation undertaken to support the primary operation of the business. This distinction between primary and secondary tasks was difficult for many respondents.

Seed tests are, in general, conducted on composite samples collected by standard sampling procedures. Seed sampling may occur during one of three stages: in the field or farm bin, while being delivered (truck sampling), or after processing. Field sampling for soybeans was very common (Table 6), but not for corn. Seed corn is normally produced under contract and is therefore

Table 2. Profile of sample firms

Firm Type	Seed Firms: Soybean Seed Firms	Seed Firms: Corn Seed Firms	Seed Firms: Total Seed Firms	Nonseed Firms	All Firms
Single branch firms	2	1	3	2	5
Main branch of multiple branch organization	4	1	5	5	10
A branch of multiple branch organization	4	2	6	2	8
Total	10	4	14	9	23

Table 3. Volume of corn and soybeans handled by surveyed firms

	Seed Firms: Exclusively Soybeans	Seed Firms: Exclusively Corn	Seed Firms: Both Corn and Soybeans	Nonseed Firms
Number of firms	5	2	7	9
Soybean (1,000 bu.)				
Mean	1,850	—	2,179	425
Range	375-7,000		5-8,300	125-750
Corn (1,000 bu.)				
Mean		220	4,437	4,910
Range		130-360	2-10,000	600-22,000

Table 4. Number of surveyed firms handling other crops

	Seed Firms (of 10)	Nonseed Firms (of 9)
Oats	1	5
Wheat	2	2
Sorghum	2	1
Sunflower	2	
Alfalfa	2	1
Rapeseed	1	

Table 5. Organization type and seed or grain handling tasks

		No. of Replies
Type of Organization		
Main Office		10
Branch Office of Multibranch Business		8
Single-Branch Business		5
TOTAL		23
Seed or Grain Handling Tasks		
Grain or Seed Grower	10	
Primary		7
Secondary		3
Grain or Seed Seller	13	
Primary		9
Secondary		4
Research Lab	8	
Primary		1
Secondary		7
Contact Grower	2	
Primary		2
Secondary		—
Seed Conditioner	15	
Primary		13
Secondary		2
Grader	14	
Primary		6
Secondary		8
Plant Introduction Facility	3	
Primary		
Secondary		1
		2
End-User (Mill/Crusher)	10	
Primary		4
Secondary		6
Testing Lab/Certifier	12	
Primary		1
Secondary		11
Distribution	1	
Primary		—
Secondary		1
Building Facilities	1	
Primary		1
Secondary		

Table 6. Number of samples per year and sample size

	Seed Firms			Nonseed Firms		
	Field	Truck	Post-Process	Field	Truck	Post-Process
Soybean						
Number reporting	7	6	7	1	5	2
No. samples per firm per year	1,556	3,963	860	2,000	1,047	494
Avg. size of samples (#)	14	8	11	2	4	10
Corn						
Number reporting	3	2	6	1	6	2
No. samples per firm per year	106	9,500	777	5,000	2,917	208
Avg. size of samples (#)	4	2	8	1	3	5

supervised by the contracting firm. Thus, there is no purchase decision made in the field. On the other hand, since soybeans are privately produced processors need to verify the field quality before purchasing.

Computer Usage and Familiarity

In profiling the firms, their use of and familiarity with computers was considered important because the proposed system could be used most productively by those with computer expertise. Of the 13 seed firms responding to this section (Table 7), nine reported currently using mainframe computers either on-site or by uplink to other facilities. For all firms surveyed a very similar share reported mainframe computer use. Nearly 75 percent of the firms had PCs, with one-half or more reporting a networked environment. On the whole, more than 80 percent used either PCs, mainframe, or remotely linked work stations. Of the staff, 40 to 50 percent of full time staff were

Table 7. Reported computer facility usage

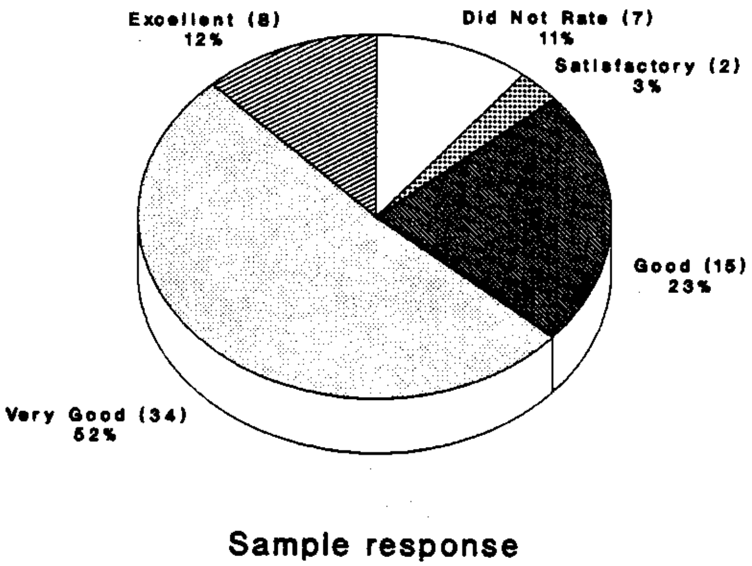
	Seed Firms	All Firms
Hardware and Personnel		
Total Number of Firms Reporting	13	23
Reporting Mainframe/Minicomputers	9	16
Reporting PC's:		
None	3	6
1 - 5	7	11
5 - 1-	3	4
> 10	0	2
Networked	4	9
Firms with Computer Facility	84.6%	82.6%
Staff Using Computer in Firms with Computer	49.7%	39.0%
Software in Use		
Spreadsheet		
Lotus	5	12
DBase	1	2
Paradox		1
Excel	1	1
Symphony	1	1
Word Processing		
Wordstar	1	1
Word Perfect	1	3
IBM-Personal	1	1
Custom Made	1	5
Statistics		
SAS	1	1
Quality Analyst		1
Sysmart		1
Other (Unspecified)	2	5

reported as computer users but in general were only competent to use application packages. There were very few users with basic computer training and the ability to program in one or more computer languages. Commonly used software is also listed in Table 7. Of spreadsheet and database software, Lotus 1-2-3 was the most common, but it was used for accounting rather than for seed quality data storage or analysis. Very few firms used statistical packages. Few firms had farm extension data and client (contract grower) databases in custom application packages. None of the firms reported having in-house hardware personnel. Given this low incidence of hardware personnel and programming capacity, the software needs to be user friendly and user support is essential if the QA system is to be widely accepted.

Response to the QA System

During each interview, detailed questions were asked about the seed or grain characteristics of interest to the firm. Then an audiovisual demonstration of the QA system was presented and its features were explained. This was followed by questions on the usefulness or applicability of the system to the firm's operation. Figure 2 summarizes the responses of the sample and the weighted industry projections. Eleven percent of the sample did not complete this section, so the projection is based on those who responded. In the sample, 12 percent ranked the system as excellent and 52 percent as very good. While it is evident that most respondents were quite impressed with this system's potential, there was some skepticism. Most of the doubts related to whether or not ultrasonic and video imaging could provide practical and dependable information about the seeds' germination capacity.

The system components and capabilities of seven different preconfigured systems (see Appendix A, p.6) were explained and respondents were asked to rank them in order of preference. The complete system outranked the others by a large margin (Table 8). The sample responses and Iowa projection are detailed separately. Ultrasonic and sizing systems scored high as the second and third preferences. Respondents indicated their most tedious task was grading the seeds and grains by size. Clorox tester and hardness tester were the lowest ranked among the configurations.



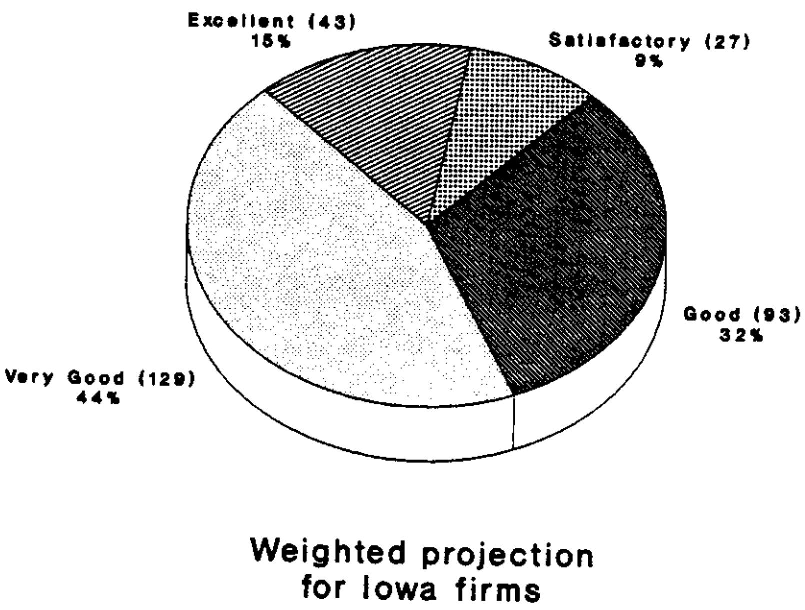


Figure 2. Overall rating of QA system

Table 8. System preference ranking

	Complete	Ultrasonic	Imaging	Clorox	Hardness	Breakage	Sizing
Iowa Projection							
RANK 1	231	23	30				8
2	2	123	18	26	10	37	78
3	19	73	60	3	44	85	12
4	0	54	95	8	26	68	16
5	30	7	8	23	57	54	52
6	4	7	62	28	45	43	42
7	4	3	1	143	49	2	22
Total	291	290	275	230	231	288	230
Sample							
RANK 1	49	10	5				2
2	3	21	17	3	5	4	13
3	5	15	19	1	4	14	8
4	1	8	8	5	10	15	15
5	3	4	6	11	15	18	5
6	2	6	7	8	17	11	10
7	3	1	2	33	11	2	8
Total	66	61	64	61	62	64	61

Demand Estimations for the Complete System

After answering questions about the usefulness of quality testing on seeds and grains, and following the system demonstration and rankings respondents were asked to provide two estimates of a fair price for their three configurations. This approach assumes that quality assurance professionals, directly involved in testing seeds, are familiar with the cost of laboratory test equipment and are either responsible for or involved in decisions to purchase such equipment.

The price guesses, averaged over all firms surveyed, are presented in Figure 3, along with standard deviations.[2] The first and second guesses were averaged. The average second guess was higher than the first. The importance of these implications is discussed later. The last three columns of Figure 3 are the average of the first and second guesses by group, namely soybean seed, corn seed, and nonseed firms. The nonseed firms priced the system somewhat lower than the seed firms.

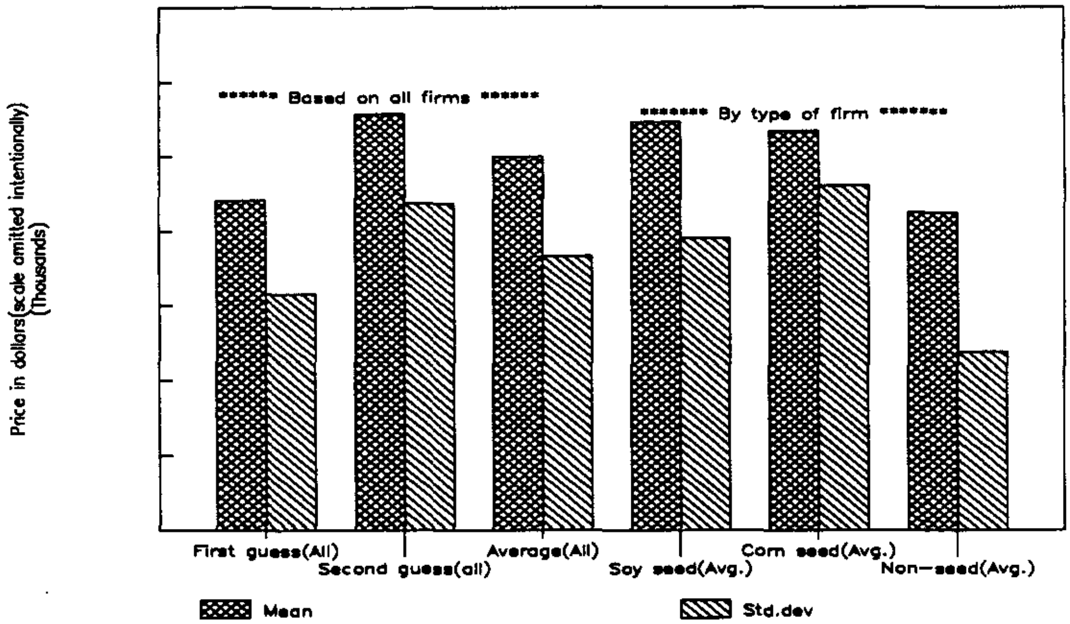


Figure 3. Price guesses of complete system, by firm type

Among the sample, the second guess was distinctly higher than the first. This is illustrated in Figure 4 where the first guess is plotted on the X axis, and the second guess on the Y axis, both with identical scales. Thus, the 45° line plots the first guess on itself. The second guess observations are scattered mostly above the 45° line, confirming the distinctly higher second guesses. It may be inferred from this that most respondents felt their first guess was underestimated.

In Figure 5 the means of the first and second guesses are plotted against the projected number of firms that priced the complete system at each price. The projection is based on both the weights of the respondents representing a firm and that firm's representation in the industry for all of Iowa firms handling seeds or grains. A double-log function was fitted to these observations to estimate the demand function. The fit had an R^2 of 83.5 percent, and an elasticity coefficient of -0.651 with a t value of 10, indicating a good fit and statistically significant coefficients. The observations were

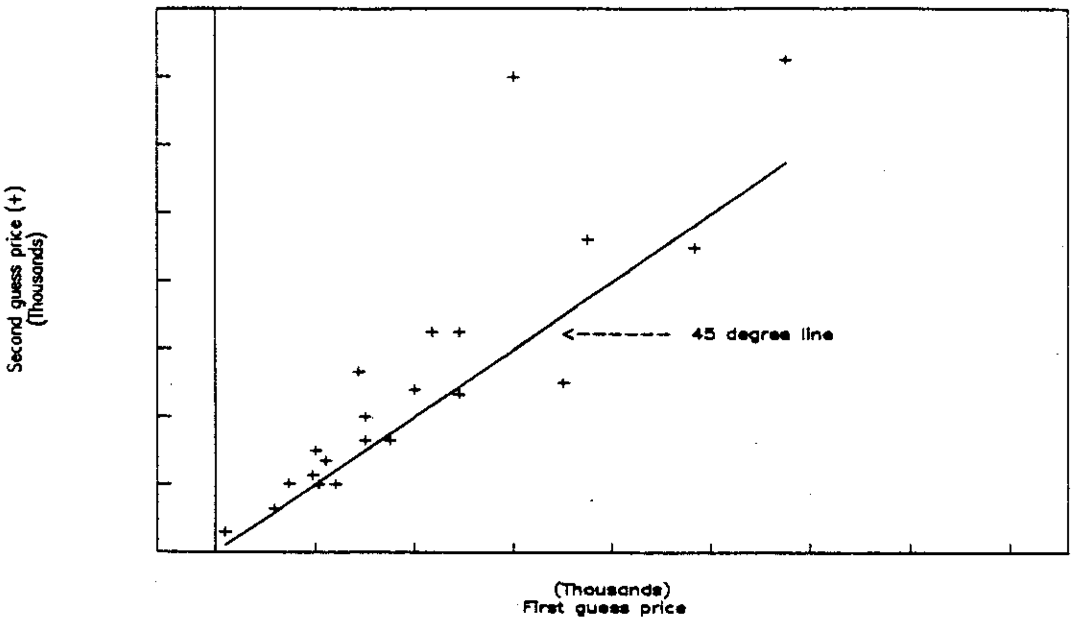


Figure 4. Suggested price observations for complete system

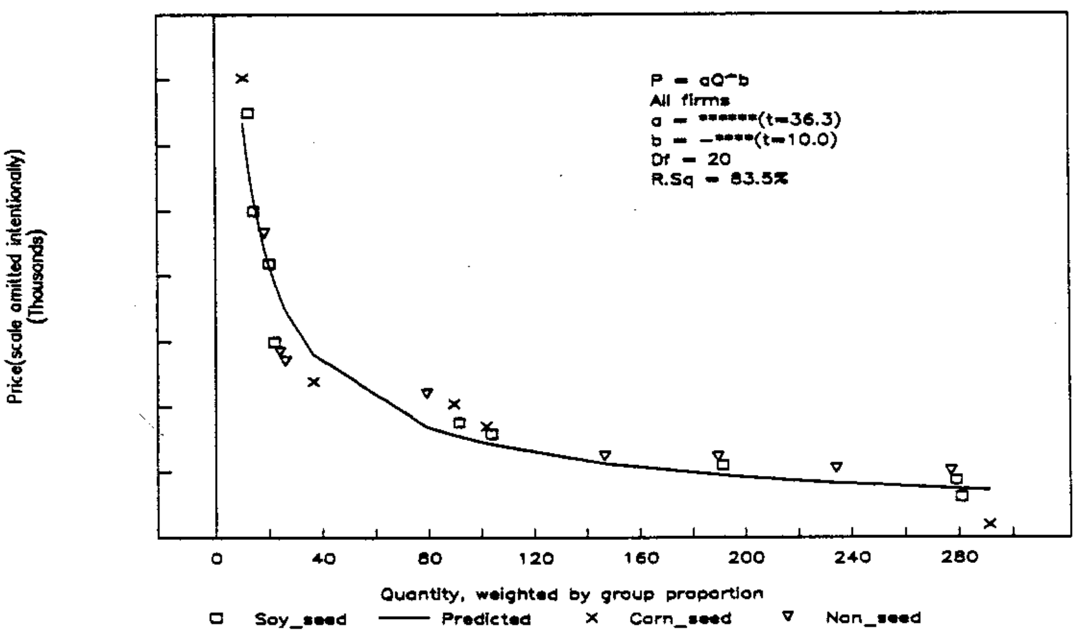


Figure 5. Estimated Iowa demand, by group observation

plotted by group to check if the nonseed firms consistently priced the system differently from the seed firms. The spread of each group negates such a suggestion. Figure 6 shows the same demand function with individual plots of the first and second guesses instead of the average. Most of the second guesses lie above the constructed demand function, especially in the price-sensitive flat portion of the demand curve.

To simplify the structure of the demand function, a straight line function was fitted to the less-than-$*****[3] region, which is the price-sensitive part of the demand (Figure 7). The resulting coefficients had high probability levels, and the goodness of fit improved, although only marginally.

The implication is that, below $*****, every price reduction of $***** can be expected to result in a one-unit increase in the quantity demanded. Given the intercept parameter value of $*****, the point of unitary elasticity (revenue maximization) is $*****.

The separate demand functions for all seed firms in Iowa and Iowa soybean seed firms also were estimated in both double-log and linear forms (Figures 8 through 11). When restricted to the less-than-$***** range, the estimated parameters and fit of the linear function performed well. The double-log functions show no distinguishable improvements. The demand of seed firms was less elastic than the all-firm estimate with a slope coefficient of −*****, and the soybean seed firm demand was even less elastic (b = −*****).

A Time Profile of Demand

The demand concept discussion showed how the quantity demanded is likely to change in response to price. While this form of demand estimation is generally adequate for a product with an established market, a new technology requires consideration of an equally if not more important aspect, the possible rate of adoption. The technology's effectiveness needs to be proven in actual use in order for the industry to adopt it. Research and technology literature emphasizes the importance of adoption patterns for effective introduction of new technology. Information on the time profile of

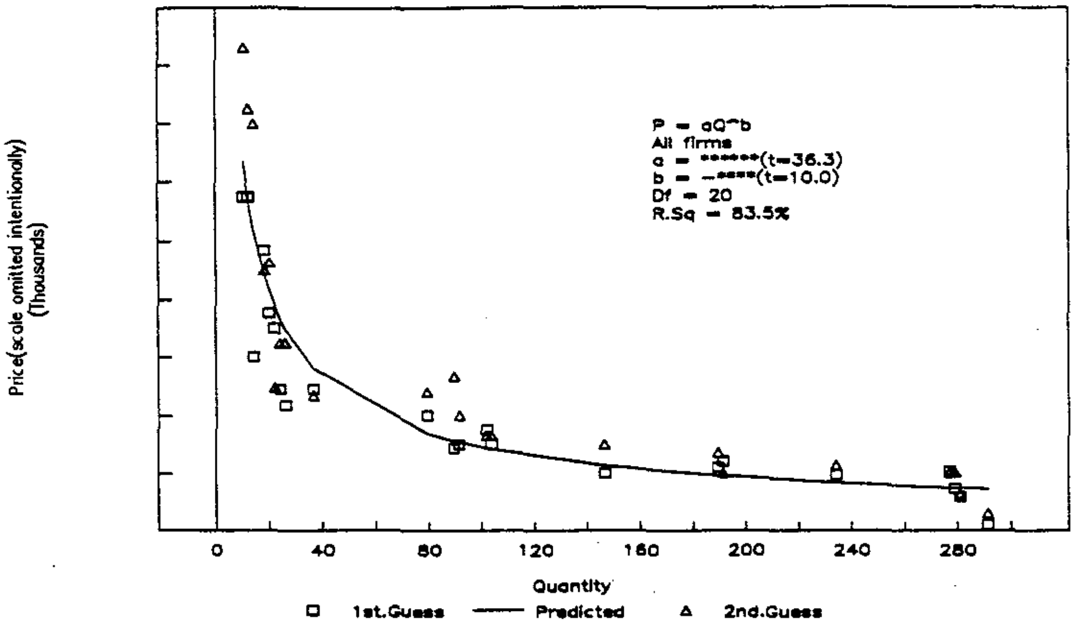


Figure 6. Estimated Iowa demand, by first and second guesses

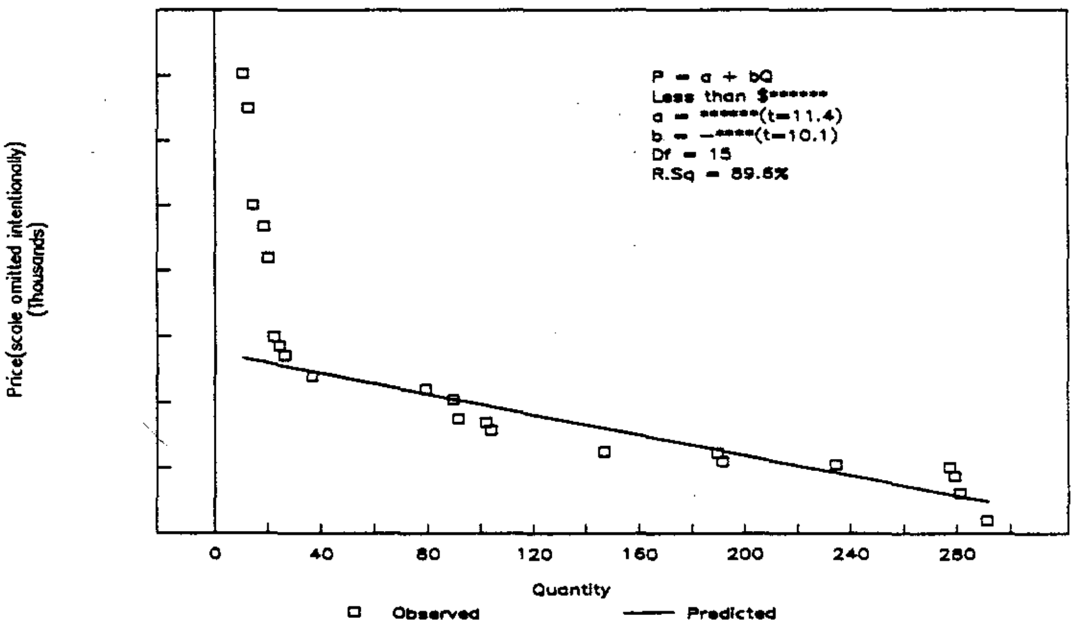


Figure 7. Linear estimation of Iowa demand for observations below $*****

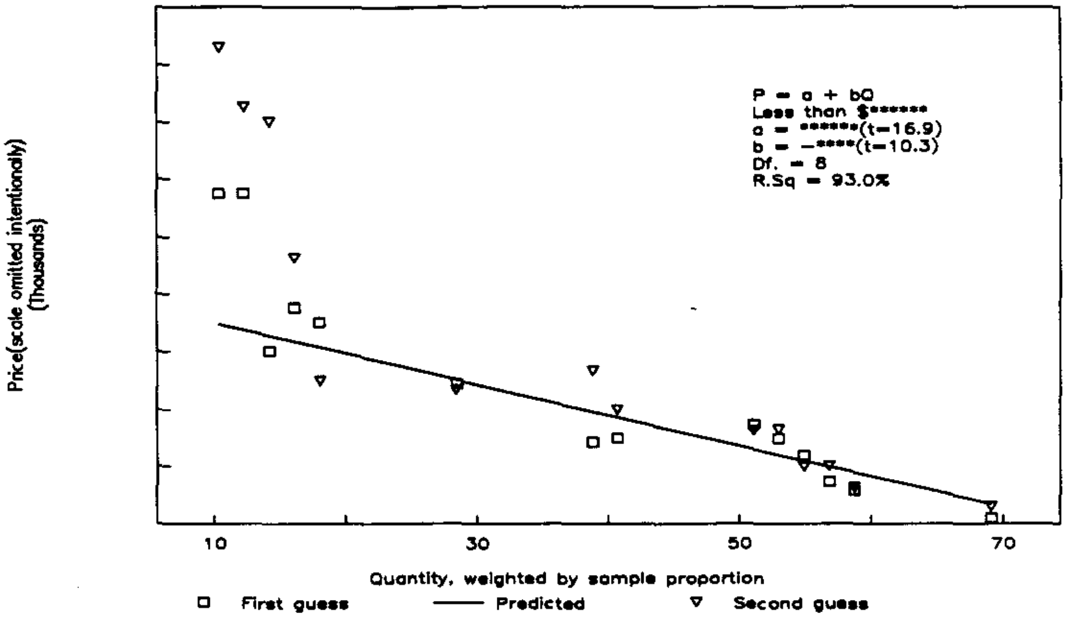


Figure 8. Linear estimation of demand within Iowa seed firms

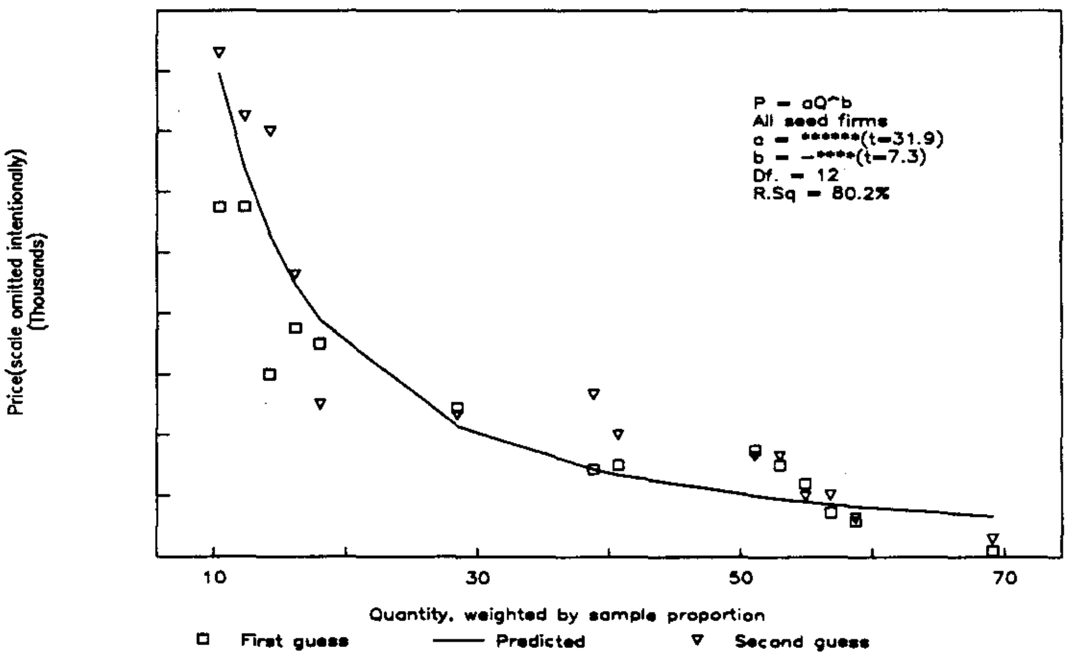


Figure 9. Log estimation of demand within Iowa seed firms

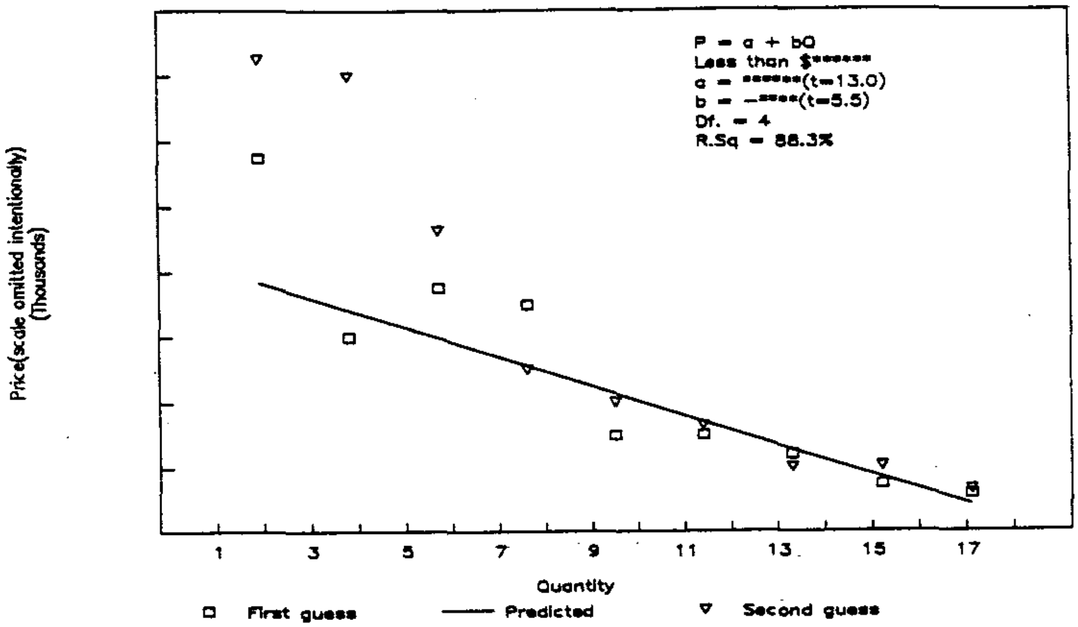


Figure 10. Linear estimation of demand within Iowa soybean seed firms

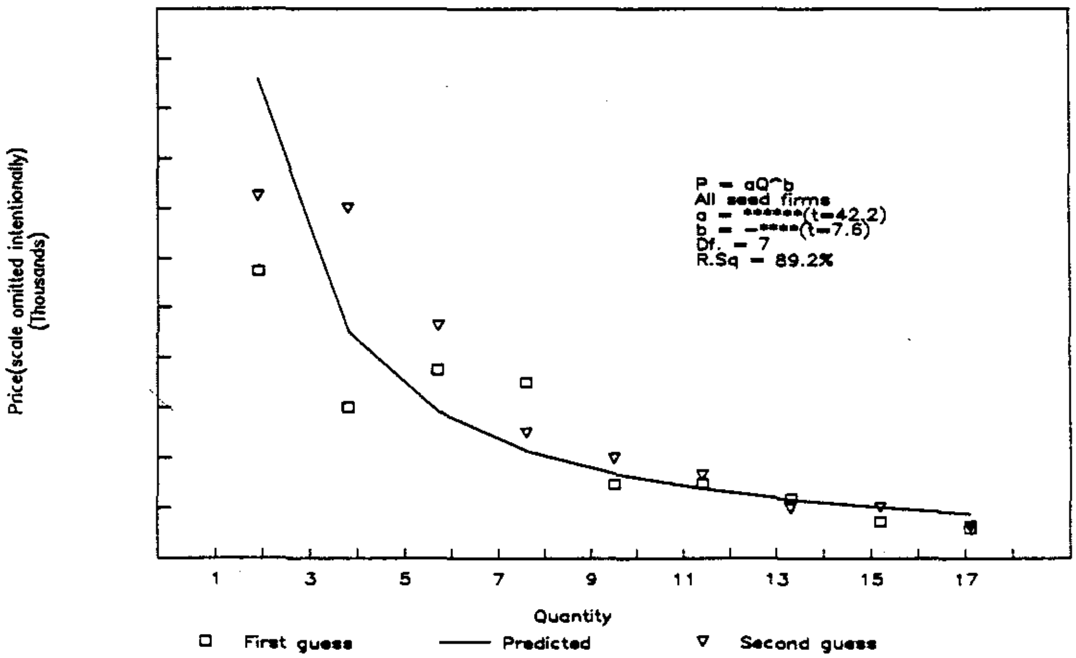


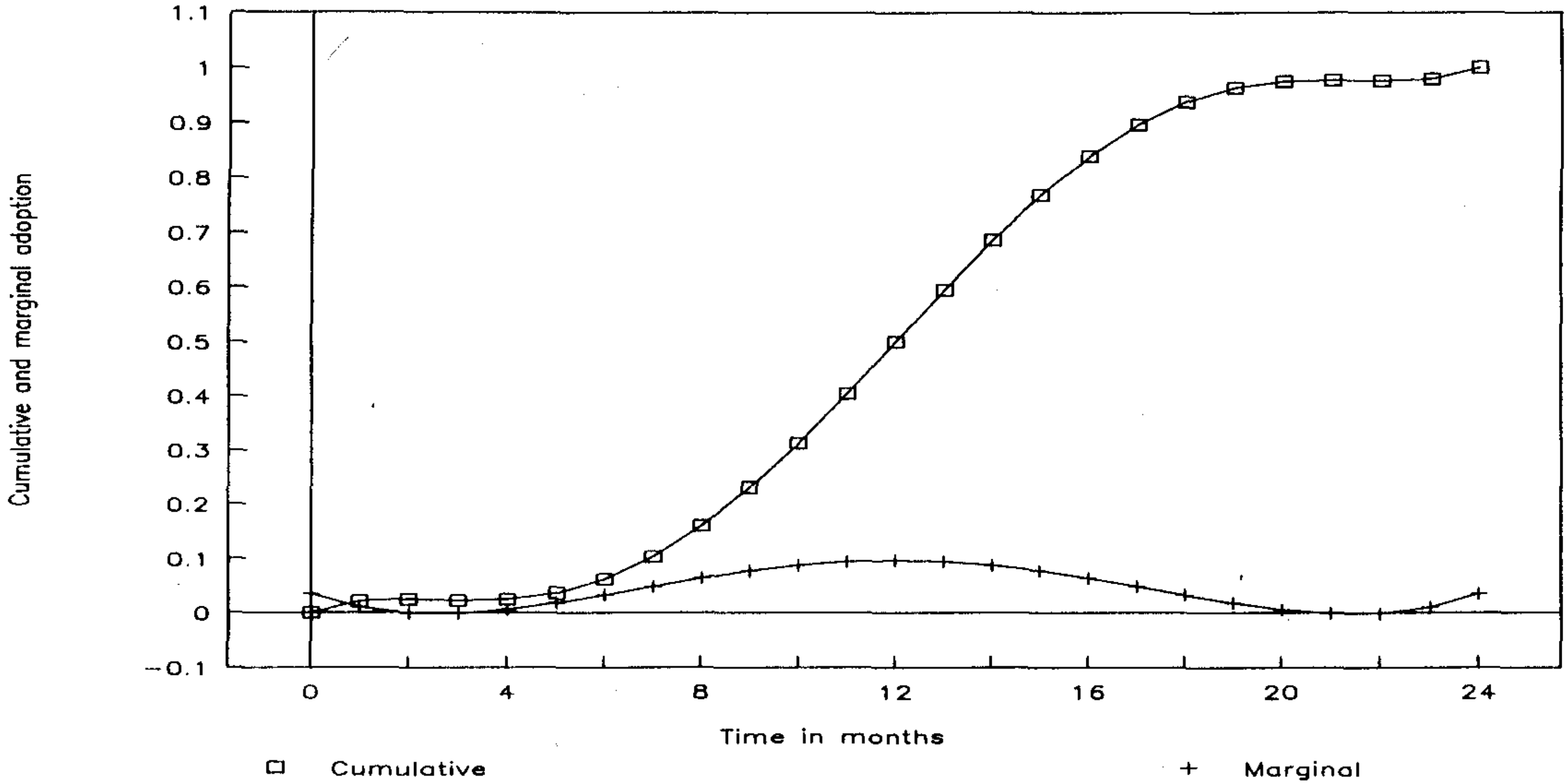
Figure 11. Log estimation of demand within Iowa soybean seed firms

adoption for a particular new technology can substantially improve management decisions, because it provides a basis for continuous evaluation of the success or failure of the proposed program.

Various technology adoption studies suggest that the rate of adoption follows a normal distribution pattern, with 2.5 percent of potential buyers adopting the new technology in one-sixth of the total adoption period, and 16 percent in one-third the time. A polynomial functional form was constructed to simulate the normal distribution with these adoption rates, and is presented in Figure 12. The X axis measures time, with an assumption of possible total adoption in 24 months. Cumulative adoption, starting from the origin, reaches 2.5 percent in four months and 16 percent in eight months. The function is not monotonically increasing at the very early and very last stages. While this monotonic characteristic would have been preferred, it may require an exponential specification. For this study, however, a simplified polynomial appears adequate since the marginal differences in the very early and late periods are relatively small.

What factors are likely to affect adoption rates? Lowering the price will increase the total quantity demanded. Apart from that, it is also likely that a reduced price will influence an earlier purchase. Therefore, the quantity demanded at any particular time during the adoption period is likely to be influenced by the price in two ways. It affects overall purchases that will be made by the end of the total adoption period, and it influences earlier adoption (i.e., it shifts the adoption function to the left).

The field effectiveness of the technology is another main contributor to demand changes in the time profile. Effectiveness is not a single factor, but a composite of several. If the early adopters (innovators) find the technology reasonably suitable for the purpose, then the rest of the industry is likely to follow. An exemplary performance will further promote adoption, while a poor performance will both delay and reduce the demand. Effectiveness is obviously a difficult, if not impossible, variable to measure in advance. It includes the actual applicability of the technology to its intended



Notes: Computed adoption rates(percent):

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Cumulative	-0	2	2	2	2	4	6	10	16	23	31	40	50	60	69	77	84	90	94	96	98	98	98	98	100
Marginal	3	1	-0	-0	1	2	3	5	6	8	9	9	10	9	9	8	6	5	3	2	1	-0	-0	1	3

Figure 12. Assumed adoption rate function
Note: 2.5% at 1/6th, 16% at 1/3rd of total time

purpose, on-stream updates and corrections based on feedback from early adopters, and user support in the early stages of adoption to prevent users from becoming discouraged. Thus, a projected or planned time profile provides a way for management to monitor and evaluate actual performance, so that necessary remedial measures can be undertaken in a timely manner.

In this context, a possible index of effectiveness was constructed with some assumptions. Assume the overall composite effectiveness can be indexed from zero to 100 percent (from totally ineffective to perfectly effective technology and follow-up support). Further assume that the currently planned program to introduce the system is indexed at 50 percent. This does not imply that the technology is only as half as good as it can be. On the contrary, because of the excellent research efforts employed to produce the technology, a marginal increase in effectiveness is likely to increase adoption by a smaller increment than any decrease in adoption resulting from a decrease in effectiveness of similar magnitude. This concept is mapped in Figure 13.[4] Given that the base scenario assumes an effectiveness of 50 percent, the total quantity demanded is estimated at this effectiveness of technology and support. If effectiveness can be increased, the quantity demanded is somewhat more than the base estimate. An exponential function with respect to effectiveness is assumed. An increase in the effectiveness to perfection increases the demand by about 15 percent over the base estimate. However, the reduction in demand due to ineffectiveness is more rapid. As the effectiveness index approaches zero, the demand drops by 80 percent of the base case.

Effectiveness also has an impact on adoption rate. It is assumed that a doubling of effectiveness from the base case reduces the total time for adoption by 15 percent, while a reduction in effectiveness of similar magnitude increases the adoption time by 80 percent. These assumptions are made merely as probable cases to illustrate the changes in time profile and provide a tool for timely management of technology introduction. They are not meant to imply that the functional form or

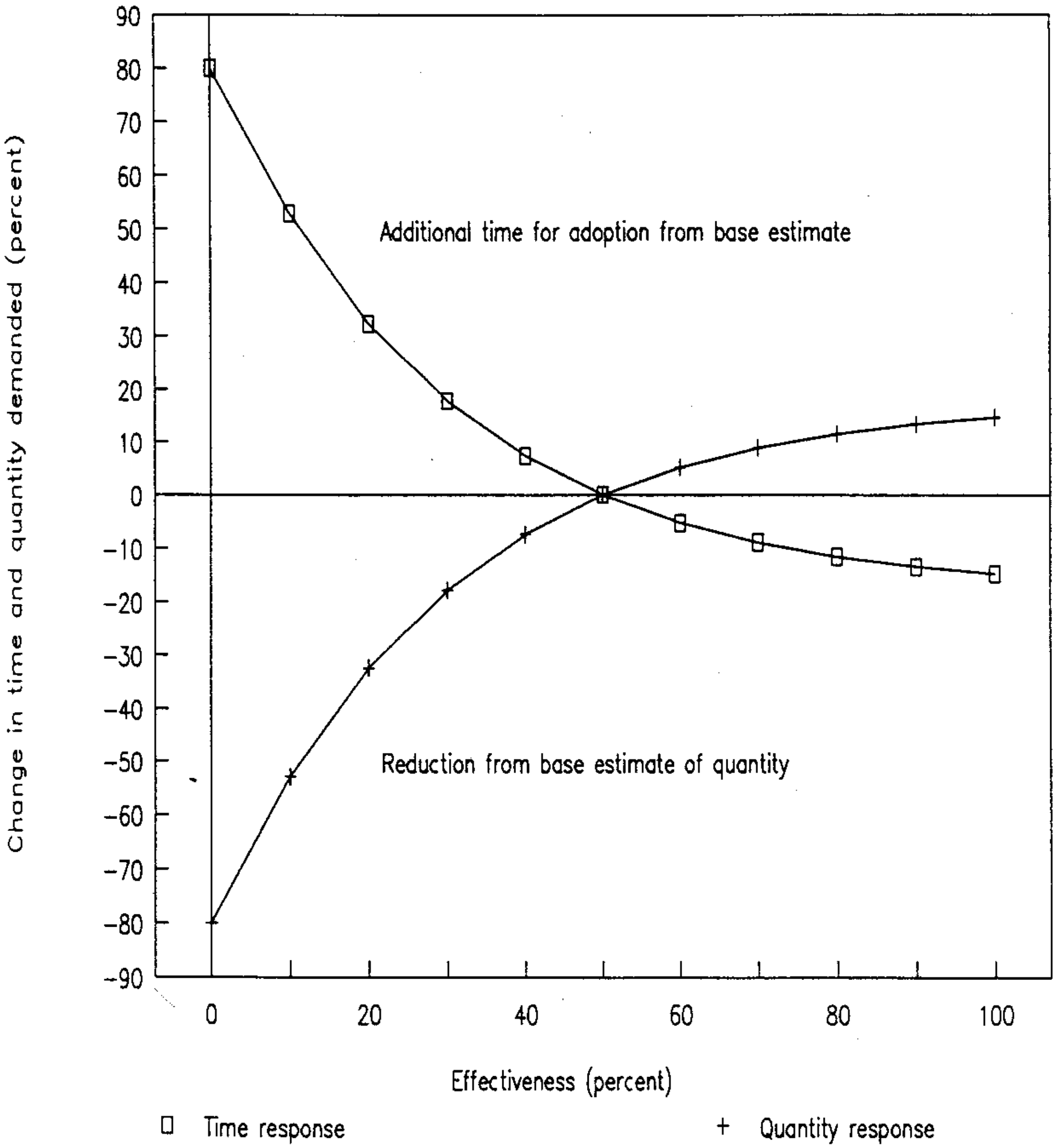


Figure 13. Time and quantity response to effectiveness, percentage change
Note: Zero at 50% effectiveness

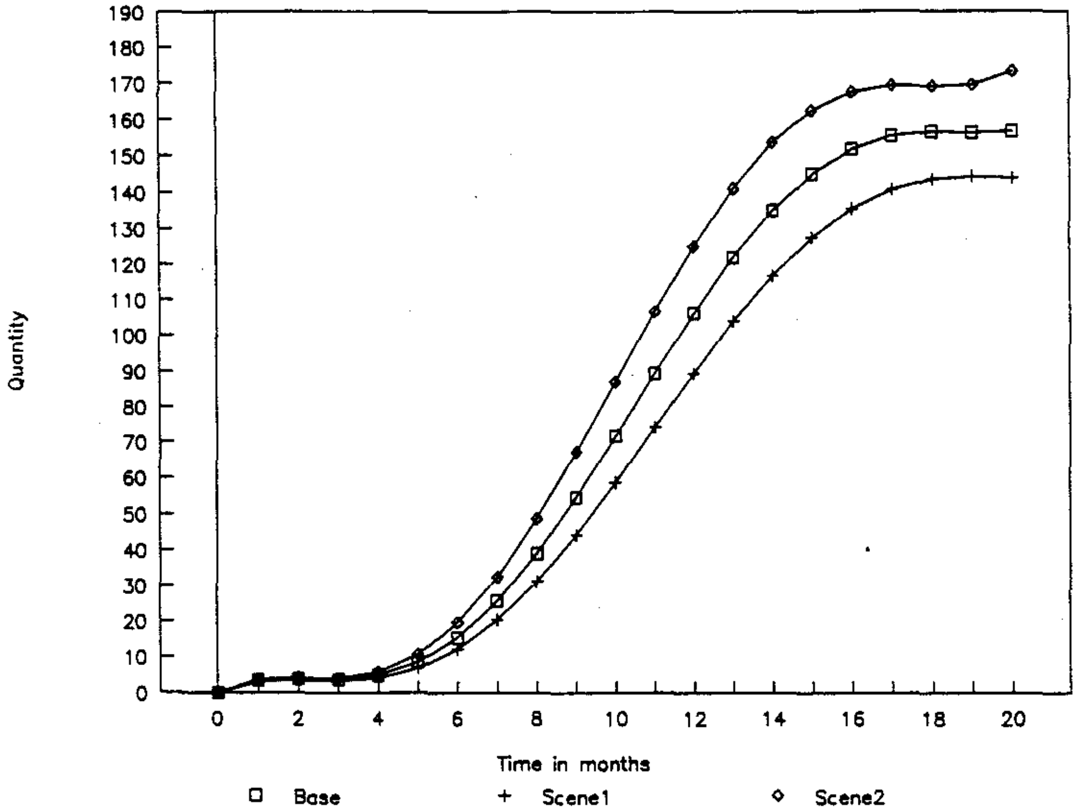
rates of changes were estimated for this study. These assumptions must necessarily be judgmental because effectiveness cannot be measured in advance.

The next three figures (Figures 14, 15, and 16) illustrate time profiles of demand based on the demand estimates and assumptions. A spreadsheet program was written to assess time profile changes in response to price and effectiveness. In Figure 14, the base scenario is plotted with a $***** price and 50 percent effectiveness. The rate of adoption follows the path shown in Figure 12. As would be expected, the base case of 161 units demanded decreases with an increase in price in Scene 1 and increases with a decrease in price in Scene 2.

The percentage changes in time and quantity demanded in response to changes in effectiveness are as mapped in Figure 13. The demand function is thus modified by a factor of (1 − Z), since as effectiveness increases, Z decreases and the quantity demanded increases. On the other hand, the time for total adoption decreases with an increase in effectiveness. In Figure 15, the prices are unchanged in all scenarios. Instead, the effectiveness is either reduced or increased from the base and resulting changes in total demand and adoption paths can be observed. Figure 16 illustrates the changing adoption paths even more clearly. While the total quantity demanded is held constant at 184 units, different time paths are generated by different combinations of price and effectiveness.

Demand Extrapolations

In this study, total demand was divided into three sectors: soybean seed, other seed, and nonseed. Demand estimates were constructed for the sectors, that is, for soybean seeds, for all seeds (soybean and nonsoybean), and for the total (all seeds and nonseeds) industry. To extrapolate the Iowa results to the United States, total U.S. demand was divided into these same three sectors. Detailed information about relative firm concentrations in each sector, the average sizes of these firms, and firm structure (types and composition of seeds or grains handled) for the United States as a whole was difficult to obtain. In the absence of such information, extrapolation of Iowa results to the



Notes:

	Base	Scene1	Scene2
Price(base price is P; p is a positive change):	P	(P + p)	(P - p)
Effectiveness(percent):	50	50	50
Quantity:	161	148	173
Time for 100% adoption(months):	21	22	20
Z (an exponential function as explained in text):	0.000	0.000	0.000

<u>Computational requirements:(price related values are hidden)</u>

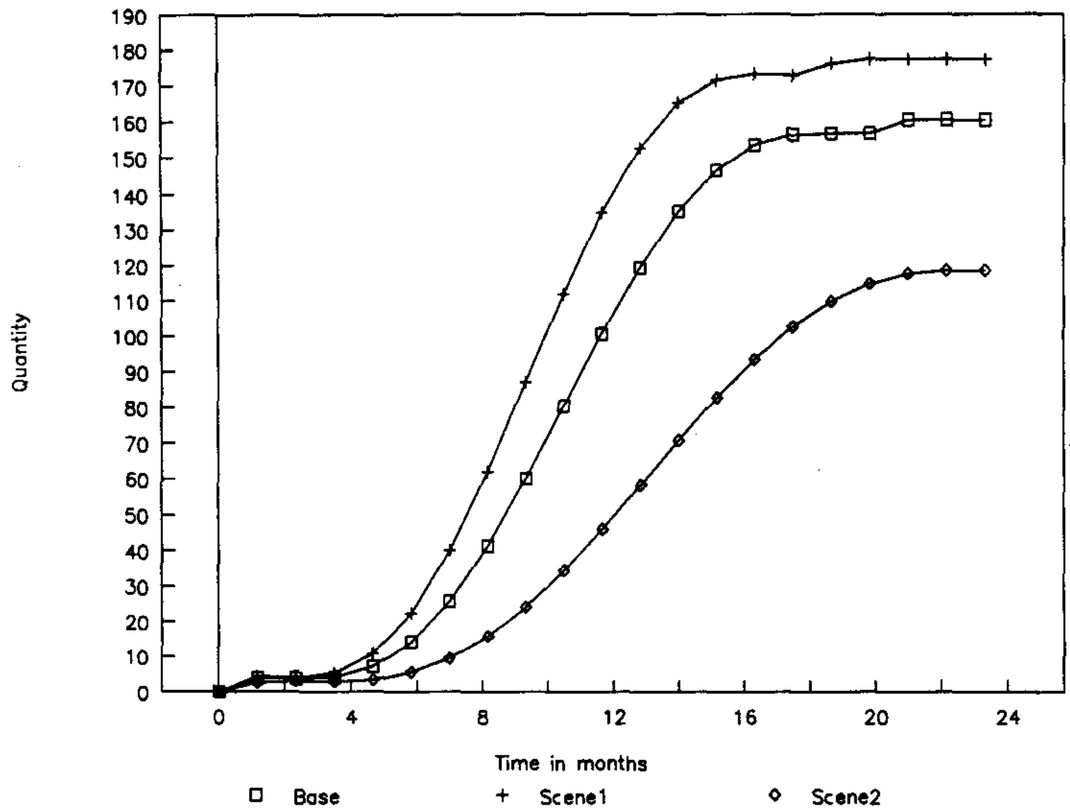
P = (alpha + beta*Q)*(1-Z)
alpha = [redacted]
beta =

T1 = 1/6
T2 = 1/3

Mu1 = 0.025%
Mu2 = 0.16 %

Time: (6 + .001*P)*(1+1/(1-Z))

Figure 14. Time profile of Iowa total demand for Case 1 based on standard adoption rates



Notes:

	Base	Scene1	Scene2
Price(base price unchanged):	P	P	P
Effectiveness(percent):	50	75	25
Quantity:	161	177	121
Time for 100% adoption(months):	21	19	26
Z (an exponential function as explained in text):	0.000	-0.103	0.244

Computational requirements:(price related values are hidden)

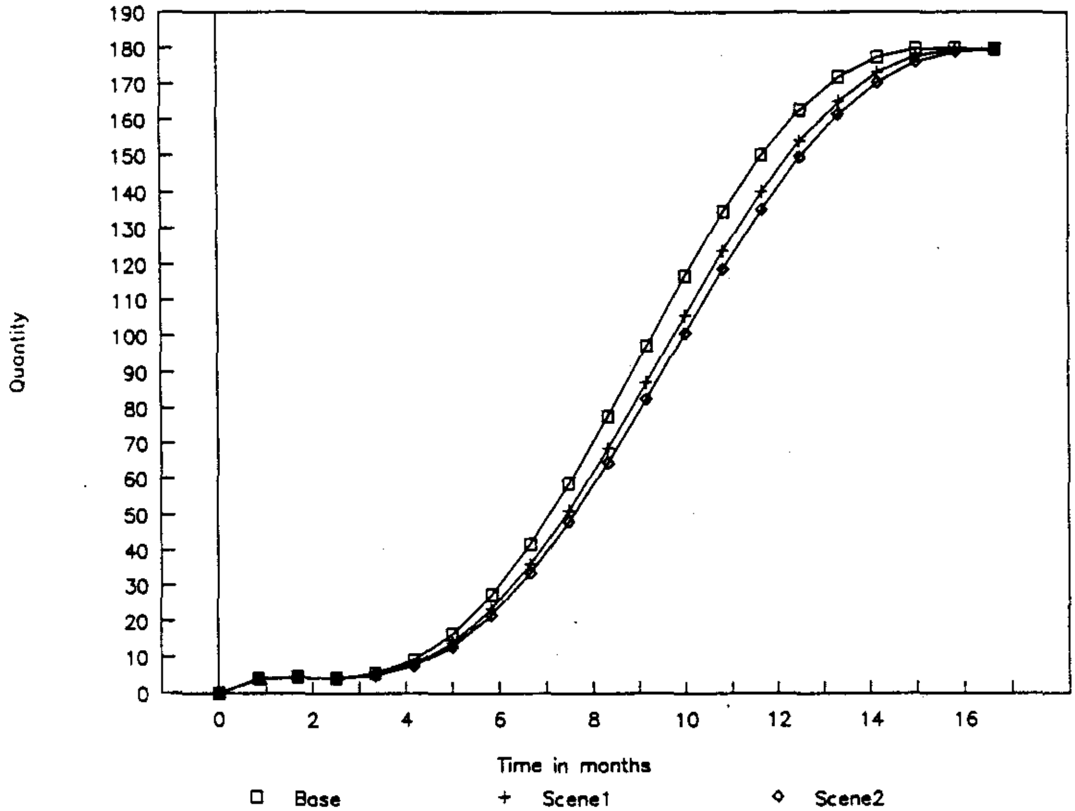
P = (alpha + beta*Q)*(1-Z)

alpha = [redacted] T1 = 1/6 Mu1 = 0.025%

beta = [redacted] T2 = 1/3 Mu2 = 0.16 %

Time: (6 + .001*P)*(1+1/(1-Z))

Figure 15. Time profile of Iowa total demand for Case 2 based on standard adoption rates



Notes:

	Base	Scene1	Scene2
Price(base price is P; p1 < p2):	P	(P - p1)	(P - p2)
Effectiveness(percent):	100	62	50
Quantity:	184	184	184
Time for 100% adoption(months):	18	19	19
Z (an exponential function as explained in text):	-0.147	-0.061	0.000

Computational requirements:(price related values are hidden)

P = (alpha + beta*Q)*(1-Z)

alpha = [redacted] T1 = 1/6 Mu1 = 0.025%

beta = [redacted] T2 = 1/3 Mu2 = 0.16 %

Time: (6 + .001*P)*(1+1/(1-Z))

Figure 16. Time profile of Iowa demand for Case 3 based on standard adoption rates

United States necessitates several simplifying assumptions. For this study, extrapolations were made on the assumption of "uniform ratios" of QA system demand to soybean seed usage.

Let Q represent the demand for QA system, and S the annual soybean seed usage (for planting), with two level subscripts, one to identify region and the other to identify sector:

$_{I, U, W}$ regional for Iowa, the United States, and the world, respectively; and

$_{S, A, T}$ sectoral for soybean seed, all seed, and total, respectively.

The first assumption is that the ratio of QA system demand for the soybean seed industry to soybean seed usage is constant across the regions. That is,

$$Q_{I,S}/S_I = Q_{U,S}/S_U, \text{ and therefore}$$

$$Q_{U,S} = Q_{I,S}(S_U/S_I). \quad (1)$$

The Iowa soybean seed sector demand function for QA systems was specified as,

$$Q = a + bQ$$

and the parameters a and b were estimated (see Figure 10).

Thus,

$$Q_{I,S} = -(a/b) + (1/b)P.$$

Using (1) above,

$$Q_{U,S} = [-(a/b) + (1/b)P](S_U/S_I)$$

$$(1/b)(S_U/S_I)P = (a/b)(S_U/S_I) + Q_{U,S}$$

$$P = a + b(S_I/S_U)Q_{U,S}$$

That is, the intercept is unchanged, while the slope is scaled by the ratio of soybean seed usage between the two regions. There is concern that the ratio of soybean seed firms to total Iowa soybean seed may be different from the corresponding ratio for the United States. However, for the conversion factor so constructed to be valid, it is not necessary that each soybean growing state outside of Iowa have similar ratios of seed firms to seed usage; rather, it is sufficient if the ratio for Iowa is not substantially different from the ratio constructed for the United States as a whole.

The U.S. soybean seed sector demand extrapolation was accomplished as follows. According to the *World Oilseed Situation and Market Highlights* (USDA 1991), the U.S. and world planted acres are 57.2 and 136.9 million acres, respectively. Iowa crop reports estimate Iowa soybean acreage at 7.9 million acres. Iowa State University Extension reports suggest a 55 pound per acre planting rate. Using these values, the Iowa, U.S., and world soybean seed usage in Iowa are computed at 7.24, 52.4 and 125.2 million bushels, respectively. This ratio of QA system demand to Iowa seed use ($Q_{I,S}/7.24$) is assumed to hold for the United States ($Q_{U,S}/52.4$) and for the world ($Q_{W,S}/125.2$). Next, using the estimate of $Q_{I,S}$, the Iowa soybean seed sector demand for the system, plus the U.S. and world demands are computed as functions of price. The validity of these extrapolations depends on how well the assumption of "uniform ratio" holds across the regions.

The next step was to extrapolate the regional demands for the all-seed sector. For this, it was assumed that the ratio of soybean seed sector demand to all-seed sector demand remains constant across the regions:

$$Q_{I,S}/Q_{I,A} = Q_{U,S}/Q_{U,A} = Q_{W,S}/Q_{W,A}.$$

These extrapolations are likely to be even more inexact because the concentrations, size, and structure of other seed firms outside of Iowa are likely to be quite different. There were no edible beans reported in the Iowa firms sampled, and the volume of other seeds and grains handled was low. Essentially, the "other seed" firms in Iowa represent only the corn seed firms.

The final step was to extrapolate the total demands for the United States and the world by including the nonseed sector. This was based on an assumption similar to that made for the all-seed sector. That is, the ratio of QA system demand for soybeans to QA system total demand was assumed to be uniform across the regions:

$$Q_{I,S}/Q_{I,T} = Q_{U,S}/Q_{U,T} = Q_{W,S}/Q_{W,T}.$$

Figure 17 shows the total demand estimates for Iowa and their extrapolation to the United States and world. It should be noted that the intercept remains the same across the demand functions, while the slopes (elasticity) decrease with increases in market size. Figure 18 plots the soybean seed sector, all-seed sector, and total world demand for QA systems. The note provides the intercepts and slopes of the computed U.S. and world demand functions, by sector, from which the system demands by sector may be plotted.

Another source of variability to consider is that the time profile of demand is also likely to differ from that of Iowa for both the United States and the world. Total adoption at 100 percent effectiveness is assumed at 18 months in the Iowa demand time profiles. It would appear reasonable to assume the total time for U.S. adoption to be somewhat more, perhaps two to two-and-one-half years, and for the world as long as three to five years.

Effectiveness of Technology

The QA system's effectiveness is related to the degree to which the various features and capabilities of the system satisfy industry needs. The survey questionnaire contained several sections relating to this topic. First, the respondents were given a list of 37 features of the QA system likely to enhance both testing procedures and data use. The total list is provided in Table 9. The respondents were asked to indicate five features of most interest to them and five features of least interest. The frequency of response is provided in Table 9, and plotted in Figures 19 through 22. These will serve as a guide when deciding where research and support need to be focused in order to develop the system. For effective planning, it may be best to categorize the features by either

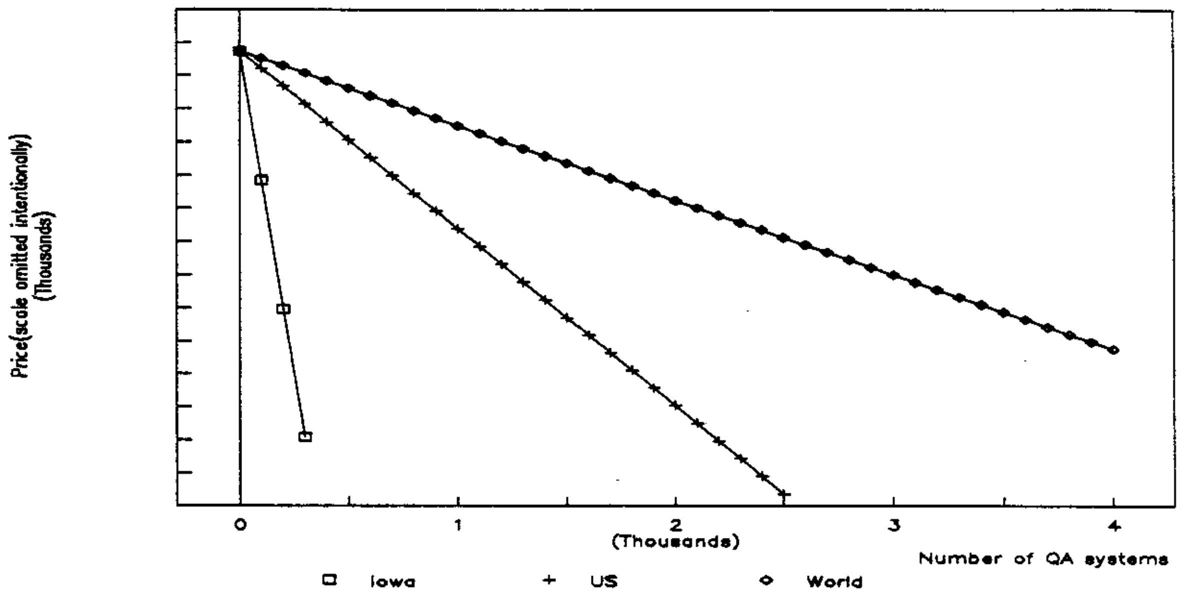


Figure 17. Linear regional extrapolations for the QA system

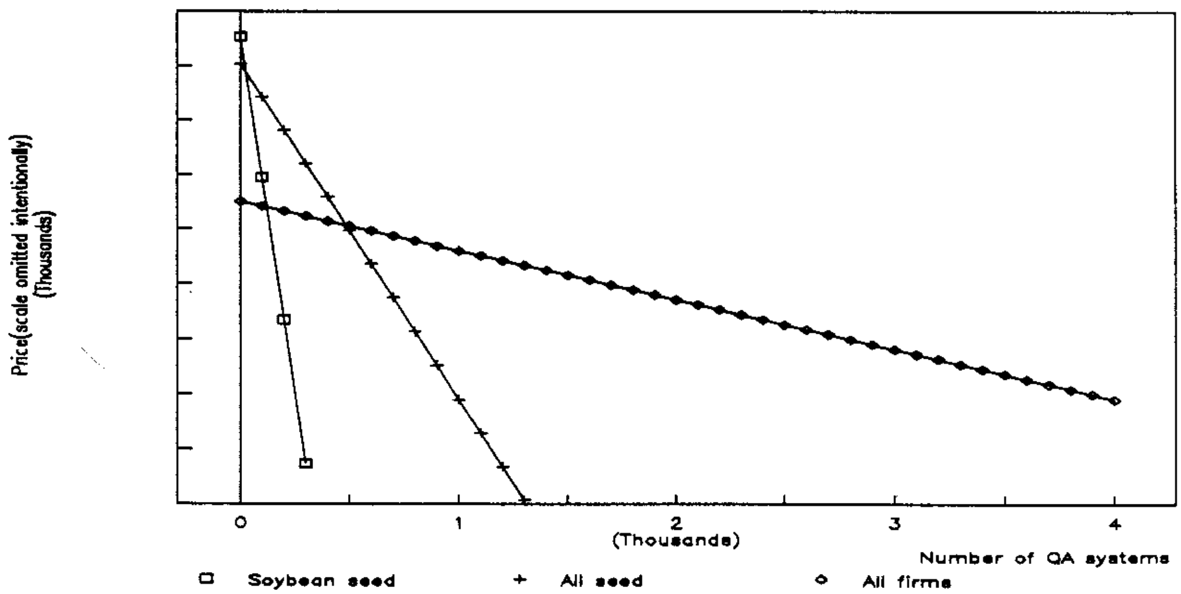


Figure 18. Linear world demand for the QA system, by sector

Table 9. Interest in specific features of the QA system

		Most Interested Feature				Least Interested Feature			
		Sample		Industry (Projection)		Sample		Industry (Projection)	
Code	Feature	No.	%	No.	%	No.	%	No.	%
25	Insect damage	15	23	71	24	1	2	1	0
26	Moldy	15	23	90	31	2	3	2	1
16	Full/shriveled	5	8	4	2	3	5	5	2
20	Splits	8	12	72	25	4	6	6	2
31	Breakage susceptibility	10	15	44	15	4	6	8	3
28	Moisture	21	32	135	46	5	8	10	4
33	Heat damage	13	20	123	42	8	12	12	4
19	Damage/chipped	27	41	159	55	1	2	14	5
1	High speed	23	35	60	20	10	15	14	5
5	Wild applications	9	14	22	8	10	15	14	5
11	Automated testing and sorting	12	18	16	6	13	20	16	5
7	Simultaneous tests	4	6	8	3	13	20	17	6
8	Adaptability	4	6	2	1	14	21	17	6
12	Flexibility in configuration	3	5	2	1	11	17	18	6
10	Less tedious	7	11	12	4	14	21	18	6
32	Stress cracks (corn)	10	15	48	16	4	8	19	7
34	Protein content	19	29	109	37	13	20	21	7
4	Increased precision	21	32	95	33	10	15	28	10
3	Economical	11	17	26	9	10	15	28	10
14	Shape	10	15	25	9	10	15	30	10
15	Color	2	3	5	2	10	15	30	10
37	Color of flour (corn)	4	6	16	5	14	21	30	10
2	Reduced subjectivity	20	30	96	33	12	18	30	10
35	Oil content	9	14	91	31	11	17	33	11
30	Hardness of seed	3	5	1	0	9	14	38	13
29	Hardness of coat (soybean)	5	8	6	2	8	12	39	13
9	Reduced work space and tools	5	8	4	2	19	29	43	15
18	Texture	6	9	8	3	12	18	48	17
27	Growth mark (soybean)	0	0	0	0	13	20	52	18
36	Ratio of s/h starch	8	12	47	16	14	21	67	23
6	Telecommunication capability	5	8	19	6	24	36	73	25
23	Bleeding hilum	0	0	0	0	15	23	97	33
24	Opaqueness	0	0	0	0	24	36	105	36
13	Size	17	26	36	12	11	17	125	43
21	Shape of hilum	0	0	0	0	20	30	126	43
17	Shiny/dull	0	0	0	0	15	23	136	47
22	Color of hilum	5	8	4	1	17	26	161	55

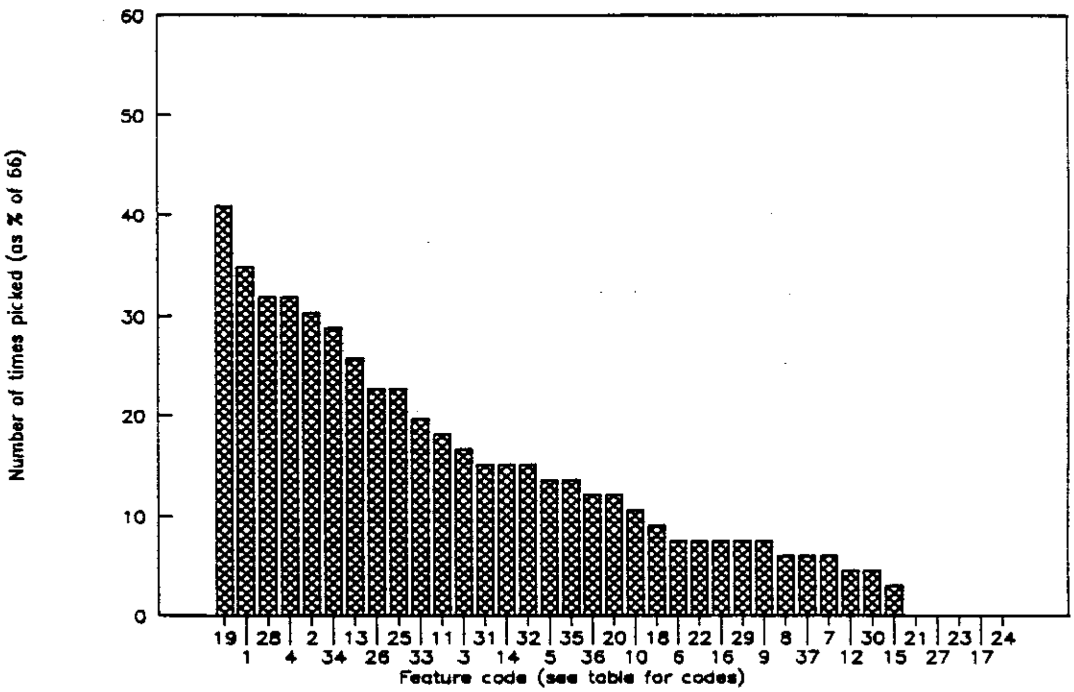


Figure 19. Most interested features, based on sample

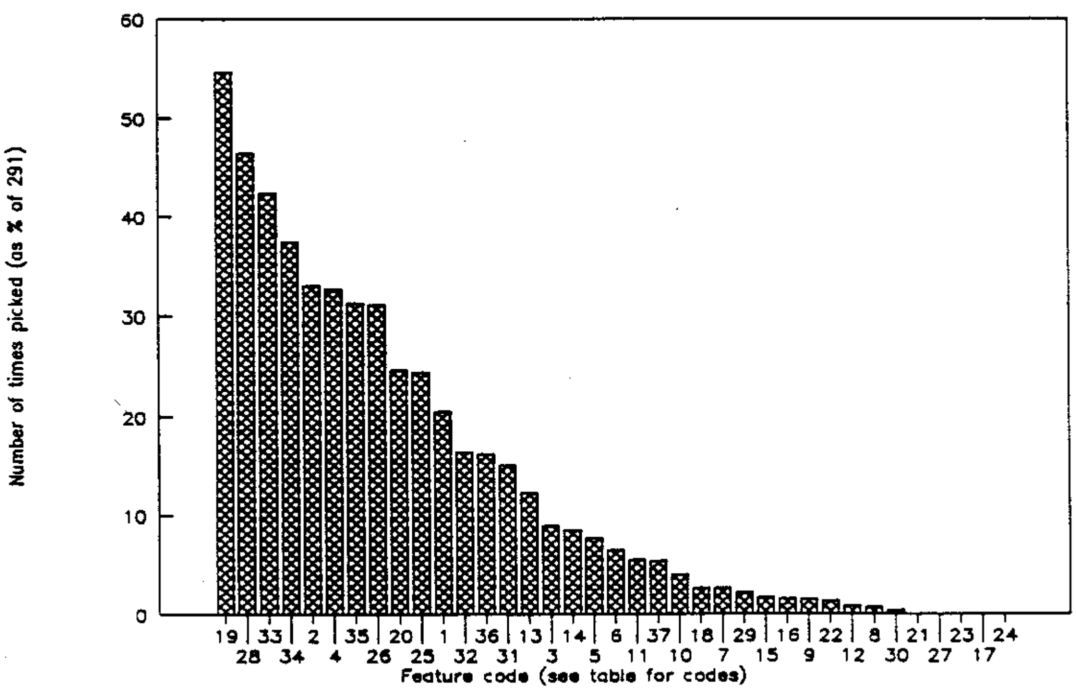


Figure 20. Most interested features, Iowa weighted projection

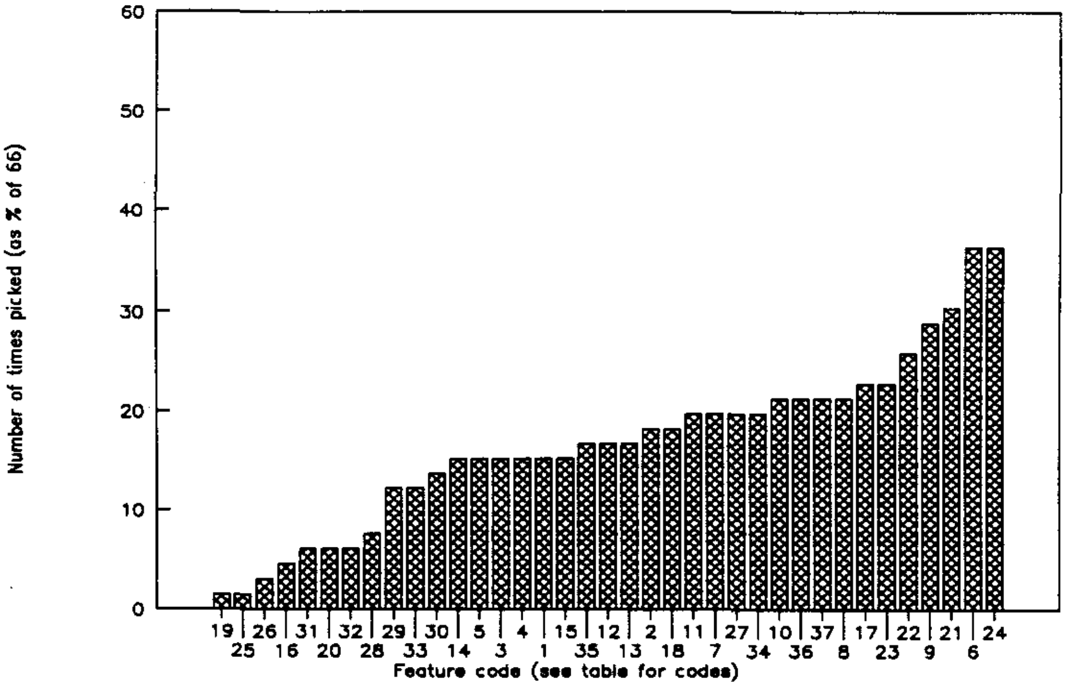


Figure 21. Least interested features, based on sample

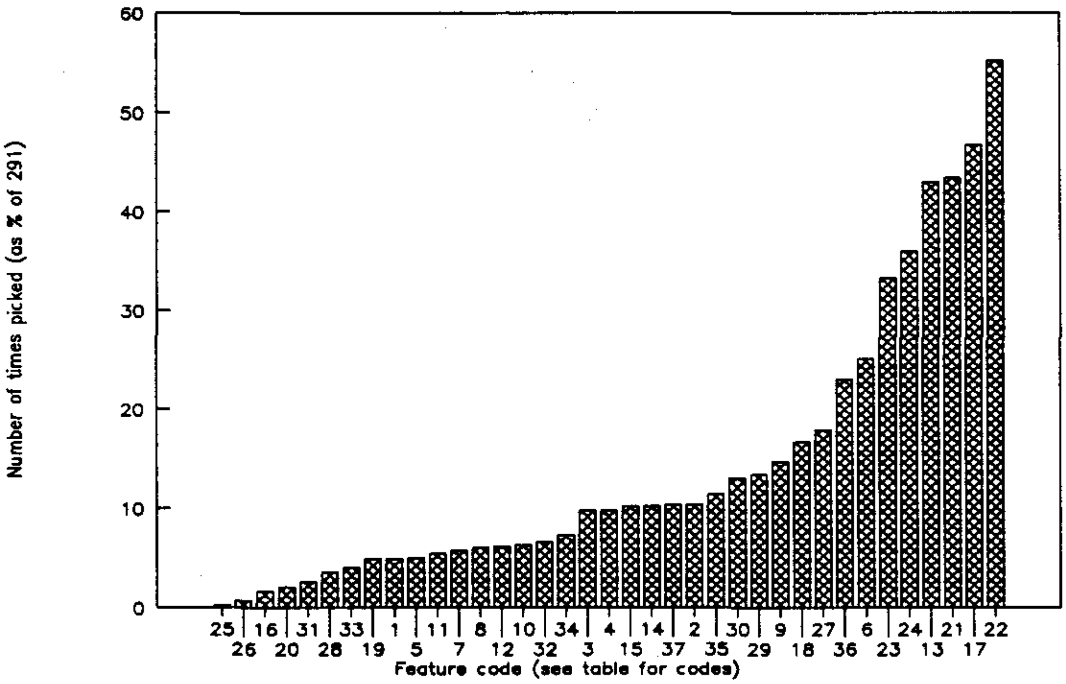


Figure 22. Least interested features, Iowa weighted projection

probable interest within the sector, or by hardware and software applicability, or perhaps by both criteria, and then reexamine what features need to be emphasized while developing the different configurations.

For instance, increased precision, high speed, and reduced subjectivity are all general features of the computerized system that were rated as most important. This indicates a positive response by the firms to newer technology adoption, but, surprisingly, telecommunications capability elicited little interest. Among the specific tests of interest, heat damage, moisture, chipping damage, and protein content may require different hardware configurations and software development. Thus it may be useful to identify which of these will be of sectoral interest for planning the configurations and options for the QA system. For example, although the ratio of soft or hard starch in general was not rated high, it is of interest only to corn milling firms, so this sector may require a specific system that includes this feature.

Further, the respondents were asked to list any other possible features that might be included in the system to improve its usefulness. The responses are listed in Table 10. Test weight was one of the main additional features suggested, because it is a legal requirement in bagging seeds. Ability to measure the share of foreign material and weeds, as well as providing a measure of probable germination, were some of the other suggestions. The respondents were also asked to identify the usefulness of different testable characteristics; that is, the relative importance of a particular characteristic, like seed size for their operation, and why it was important. Splits, damage, moisture, and foreign material were the characteristics most frequently considered essential (Tables 11 and 12). A large number of such quality parameters are examined to improve visual appeal, to indicate germination potential of seeds, or because of legal requirements.

Table 10. Additional features suggested by firms

Additional Features	Frequency
Automated Feed for Multiple Samples	1
Bar Code Utilization	1
Carotene/Zanthephyll Content	1
Correlation with Germination	2
Dirt	1
Embryo Anatomy	1
Foreign Material	3
Interface with Mainframe Program	1
User Friendliness	1
Fast Enough to Allow for Adequate Through-Put	1
Portable Subsystem for Testing at Truck	1
Protein Content	2
Rank Total Value of Seed, Based on Quality	2
Soybean, Corn Heat Damage	1
Breakage Susceptibility	1
Moldy	1
Seeds per Pound	1
Starch Content of Corn	1
Swelling, Softness, Etc.	1
Test Weight	8
Testing of Steeped Corn for Moisture	1
Weed Seed	3

Use of External Test Laboratories

From the survey results it does not appear that the seed or the nonseed firms use extensively or are aware of private testing laboratories in Iowa (Table 13). In general, the firms use their local facilities or send the seeds to their research or testing branches. Most of the exporters (elevators) reported sending samples to federally operated testing laboratories as a legal requirement. Several of the firms send samples to the Iowa State University Seed Science Laboratory for germination and disease identification tests, but the number of such samples was quite small. When asked if the firms were aware of any private testing facilities, more than one-half of the firms were unable to name a single such facility. The others listed out-of-state facilities in Illinois, Indiana, and Georgia. Some firms have used these private labs, but only for detailed testing for specific diseases and germination capacity. Hence, present demand for the QA system by private Iowa facilities appears negligible.

Table 11. Soybean test characteristics

	Importance			Purpose codes					
	Essential	Useful	Not Useful	VA	UN	VI	DI	GM	LR
Foreign Seeds	10	2		5	3	1			12
Noxious Weeds	8	4	1	4	2	1			12
Other Weeds	9	3	1	3	1	1			11
Size	6	6	5	5	5			1	1
Shape	2	7	7	5	5			1	
Color	7	7	2	7	2	2		2	
Full/Shriveled	9	7		9	6	2	1	2	1
Shiny/Dull	4	6	6	7	1	2		1	
Texture		4	12	4	1		1		
Damaged	12	3		6	3		3	7	2
Splits	14	2		4	3	6			4
Shape of Hilum	3	9	4	3	2	3			
Color of Hilum	7	1	6	4	3	6			
Opaqueness	1	3	12	2	3				
Insect Damage	9	7		6	2		2	7	2
Moldy/Discolored	13	3		7	2		5	7	2
Bleeding Hilum	4	4	6	7	3		4	2	
Growth Marks	1	6	8	6	1			3	
Moisture	15	1		2	1		1	5	5
Hardness of Coat	1	7	6	1		2		4	
Breakage Susceptibility	4	8	4	2	1	2	1	6	
Heat Damage	9	5	2	3	1	1	1	7	3
Protein Content	5	6	5	2	1	2			1
Oil Content	2	8	6	1	1	3			1
Other									
Dirty Seed	2			2			1	2	
Stress Crack	1	1						2	
Test Weight	2	1		1	1				
Cracked Coat	1							1	
Foreign Material	1			1	1				
Seed Count	1			1	1				

Note: Purpose codes:

VA Visual appeal
UN Uniformity (grading)
VI Varietal identification
DI Disease information
GM Germination capacity
LR Legal requirement

Table 12. Corn test characteristics

	Importance			Purpose codes					
	Essential	Useful	Not Useful	VA	UN	VI	DI	GM	RL
Foreign Seeds	12	2		2	3	2			10
Noxious Weeds	8	2	4	1					14
Other Weeds	6	4	4	1					13
Size	7	4	4	5	3				
Shape	5	2	8	5	4				
Color	5	7	3	5		3	1		1
Full/Shriveled	4	4	6	5				3	1
Shiny/Dull	3	2	9	5		1			
Texture	2	2	10	4	1	1			
Damaged	12	2		6			1	4	3
Opaqueness	1	1	10	3				1	
Insect Damage	12	2		5				5	4
Moldy/Discolored	12	2		5				5	5
Moisture	13		1	2	1			4	3
Hardness of Coat		3	11	2	1			2	
Breakage Susceptibility	1	6	7	2	1			3	
Stress Cracks	8	3	1	2	1			3	3
Heat Damage	4	6	4	2				5	1
Protein Content	2	6	6			2			
Oil Content	2	4	8			2			
Other									
Genetic Purity	1								
Length	1								
Test Weight	2								1
Inert Matter	1								
Germination	1							1	2
Seed Count	1								2

Note: Purpose codes:
- VA Visual appeal
- UN Uniformity (grading)
- VI Varietal identification
- DI Disease information
- GM Germination capacity
- LR Legal requirement

Table 13. Testing laboratory use or familiarity

Name and Location	Reported Using	Known Facilities
AGP, Sheldon	1	
Asgrow/Ames Lab	2	
Asgrow-Oxford, Indiana		1
Belmond	2	
Calif. State Lab & Idaho State Lab	1	
DeKalb, Illinois	1	1
Federal Labs, Iowa	2	
Fremont Grain Inspection	2	
Halsey Seed Lab, Georgia	2	1
Iowa Testing, E.G. Labs.		1
Indiana Crop Improvement, Indiana	1	1
ISU/Ames Lab	7	
NRK Central Lab	1	1
Princeton, Illinois		1
Sanitation Labs	1	
Sioux City Federal Grain	1	
Texas Dept. of Ag.	2	
University of Illinois	1	

However, if the QA system can be established as dependable testing and grading equipment with high speed and low cost, and perhaps even as standardizing equipment, then this may encourage the growth of private testing and grading stations within the state.

A Closer Examination of the Market for the QA System

There are two aspects of the demand estimations that require closer examination. First, it was noted that the demand function has a relatively inelastic or steep-sloped segment above $***** and a price-sensitive segment below that price. It thus may be possible to divide the market into one segment requiring very precise, highly specialized testing equipment and the other requiring a more general grading equipment. Next, the estimated demand function was based on the complete system configuration. All but one of the firms ranked this system between first and third and provided a price estimate for it. However, it may be possible to market subsystems of special interest to those with limited requirements.

The overall system system was rated "excellent," "very good," or "good" by almost 90 percent of the industry. Price suggestions were examined by these three ratings. Figure 23 depicts the price relationship by rating and firm type based on all respondents. Figure 24 provides the percentage of respondents giving these ratings. Among the soybean seed industry, 30 percent rated the system as "excellent," and their mean price estimate was distinctly higher than those who rated the system as either "very good" or "good." A similar price difference can be observed in the case of "all seed firms," although the share of "excellent" ratings was only about 20 percent. The "excellent" rating was in general among the larger establishments, and hence these firms are likely to purchase high quality equipment at premium prices. Among the nonseed firms that require specific features, the overall rating was not as positive and their price suggestions also reflect this. Hence, subsystem configurations may be better suited for this market.

Finally, it is useful to compare the relative price suggestions across configurations. Table 14 is a matrix of the price ratios, with the lower left triangle providing statistical estimates. The estimated price ratio b is listed along with the t value, degrees of freedom, and R square. For example, the top estimate of b = 0.592 is the average price of the imaging system (row title) compared with the average price of the complete system (column title). Similarly, the price ratios of the different configurations can be read from the matrix. The diagonal elements are unity and omitted from the table. The upper right elements can be computed as the inverses of the corresponding lower left elements. The ultrasound and imaging subsystems were priced at 60 to 80 percent of the complete system. The Clorox tester was chosen by so few respondents it was omitted from this table. The price relationships between the main configurations of interest are given in Figure 25. The straight line reflects the predicted relationship.

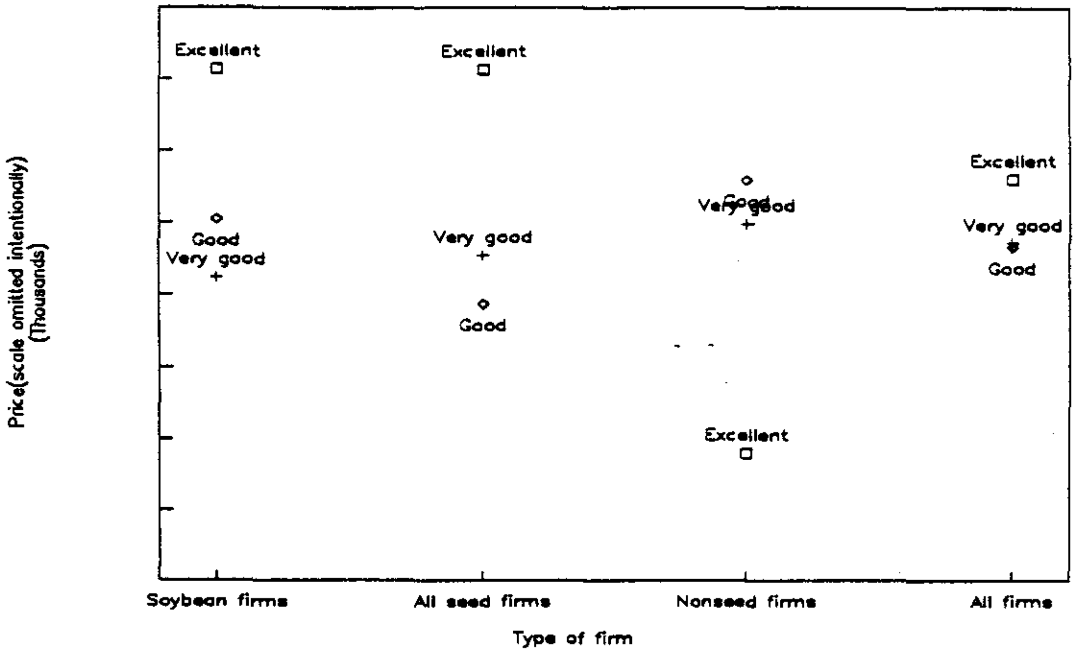


Figure 23. Mean price for complete system, by firm type and overall rating

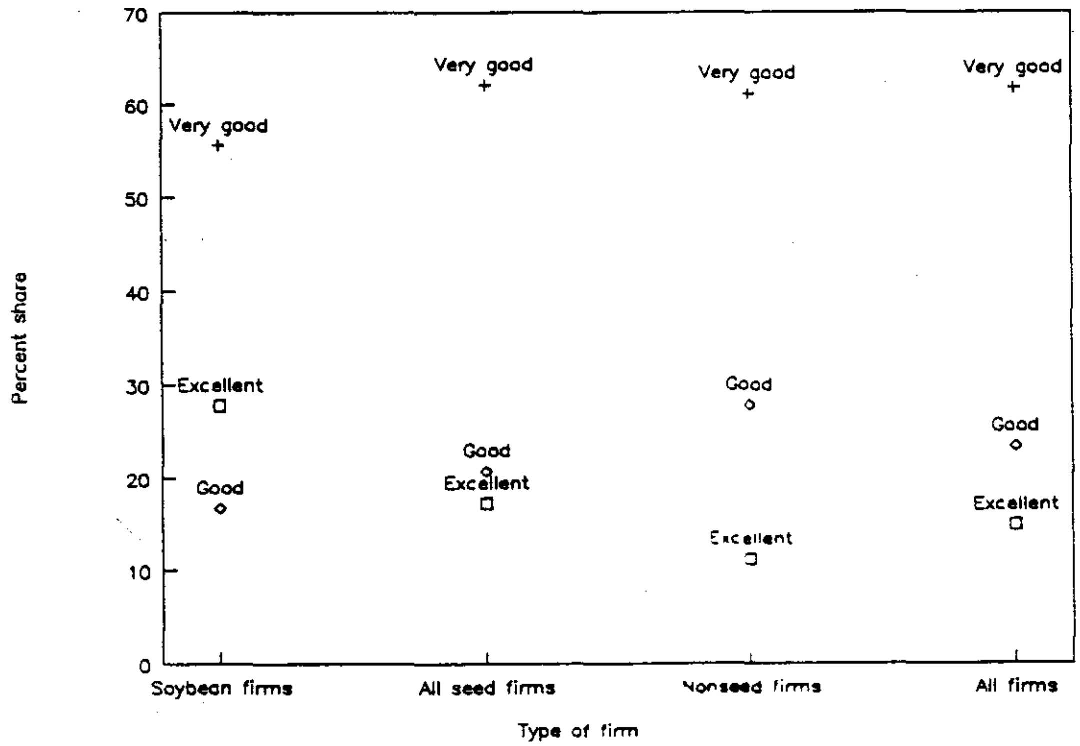


Figure 24. Share of "excellent," "very good," or "good" ratings, by firm type

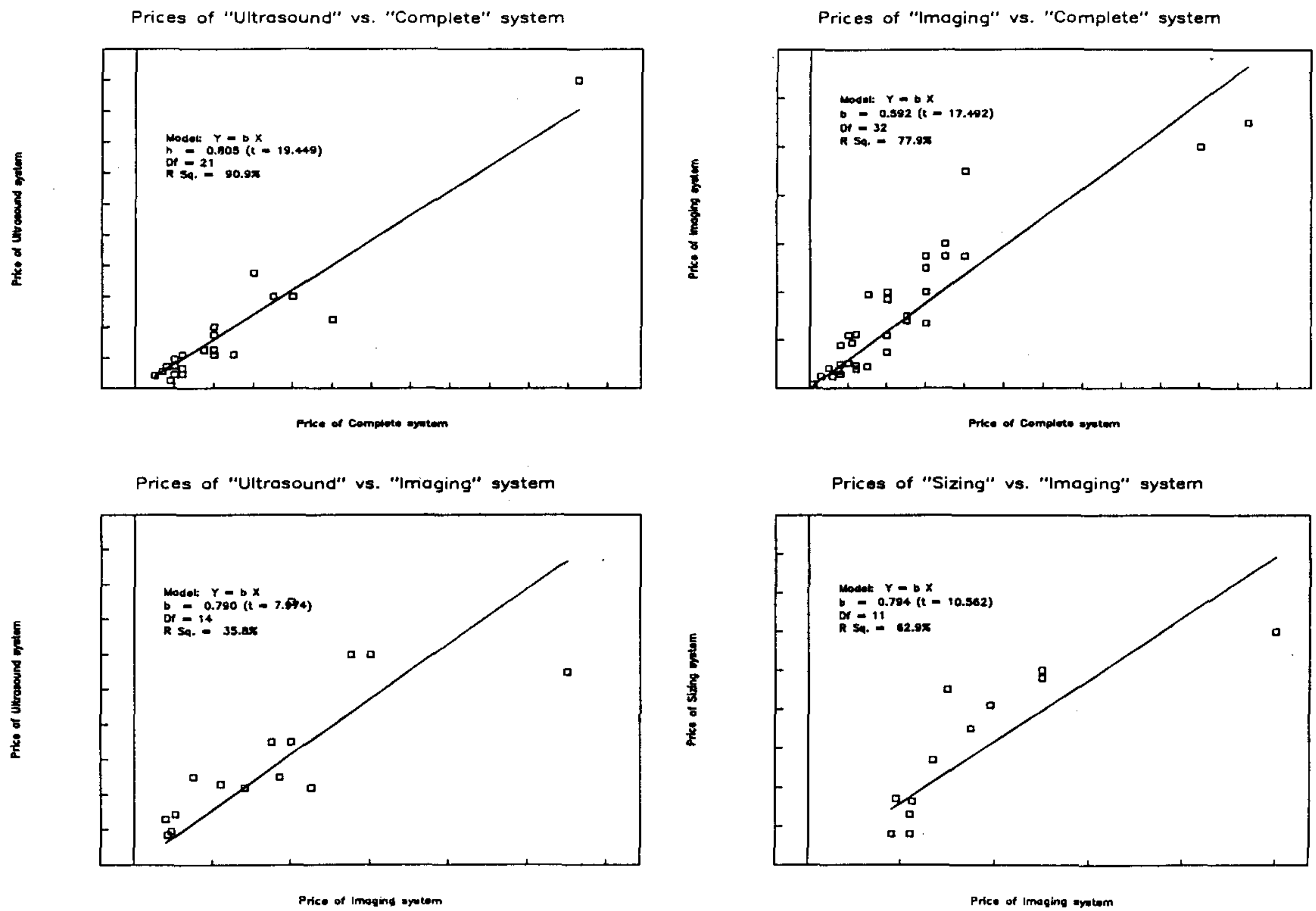


Figure 25. Price comparisons among selected configurations, observations, and estimated trend line

Table 14. Estimated demand price ratios of configurations

	Complete	Imaging	Ultrasound	Sizing	Breakage
Complete					
Imaging	b = 0.592 t = 17.49 Df = 32 R.Sq. = 77.9%				
Ultrasound	b = 0.805 t = 19.45 Df = 21 R.Sq. = 90.9%	b = 0.790 t = 7.97 Df = 14 R.Sq. = 35.8%			
Sizing	b = 0.343 t = 6.58 Df = 14 R.Sq. = 9.5%	b = 0.794 t = 10.56 Df = 11 R.Sq = 62.9%	b = 0.612 t = 5.29 Df = 5 R.Sq. = 22.6%		
Breakage	b = 0.279 t = 7.18 Df = 12 R.Sq. = 45.8%	1 Observation (b = .600)	b = 0.813 t = 14.87 Df = 7 R.Sq = 91.0%	1 Observation (b = .744)	

The subsystem demand functions estimated from the respondents ranking them 1 to 3 are provided in Table 15. While the complete system demand function was estimated from all firms, the different subsystems were ranked within 1 to 3 by less than all the firms. The degrees of freedom plus two in the estimations in Table 15 equals the number of firm observations used in each of the demand functions. In some cases observations above $***** were excluded, as discussed previously. Imaging and ultrasound subsystem coefficients were estimated from 19 of the 23 firms, and may closely approximate the total market. The sizing and breakage system observations are relatively few so the estimated coefficients must be interpreted with caution. Finally, Table 16 details the frequency with which each preconfigured system was ranked between 1 and 3. The complete system was consistently ranked high by all firm types. Of the subsystems, there was a higher preference for the ultrasound subsystem among the nonseed firms, while the seed firms showed a preference for imaging

Table 15. Subsystem demand function estimates

System	All Firms	Seed Firms
Complete	(For < $*****)	(For < $*****)
a	27,483	$*****
(t)	11.4	16.9
b		
(t)	10.1	10.3
Df.	15	8
R.Sq.(%)	89.6	93.0
Imaging		
a		
(t)	8.1	7.8
b		−334.3
(t)	11.6	
Df.	17	11
R.Sq.(%)	88.7	87.2
Ultrasound		
a		
(t)	5.8	19.6
b		
(t)	7.9	18.4
Df.	17	10
R.Sq.(%)	78.7	97.7
Sizing		
a		
(t)	8.6	19.6
b		
(t)	10.1	18.4
Df.	11	10
R.Sq.(%)	90.3	97.7
Breakage		
a		
(t)	10.3	
b		Not enough
(t)	10.67	observations
Df.	9	
R.Sq.(%)	91.5	

Note: Not enough observations for clorox and hardness testers.

Table 16. Frequency of ranking, 1 to 3

	Soybean Seed Firms		All Seed Firms		Nonseed Firms		All Firms	
	No.	%(of10)	No.	%(of 15)	No.	%(of 9)	No.	%(of 24)
Complete System	9	90	14	93	8	89	22	92
Ultrasound Subsystem	9	90	11	73	8	89	19	80
Imaging Subsystem	9	90	14	93	6	67	20	83
Sizing Subsystem	5	50	10	67	3	33	13	54
Breakage Tester	4	40	6	40	5	56	11	46
Hardness Tester	0	0	3	20	4	44	7	29
Clorox Tester	1	10	3	20	1	11	4	17

subsystems. Seed firms also showed some interest in the sizing subsystem. Breakage and hardness testing subsystems may have a market among the nonseed sector.

Summary and Implications

All of the soybean and corn seed firms, without exception, expressed interest in the QA system as a potentially useful, if no indispensable, tool for QA programs. Among the nonseed firms, the elevators and millers showed limited interest while feed manufacturers showed little or not interest. Sector-by-sector demand schedules were identifiable, and national and global extrapolations of demand were made using somewhat restrictive assumptions due to the lack of data on number and size distribution of seed and grain firms outside of Iowa. The demand schedules evidence a clearly bi-segmented market, with one segment relatively price insensitive. This segment represents the larger seed firms of Iowa where precision and detailed seed testing are of primary importance. Another observation of interest was that responders themselves considered their responses to be somewhat conservative. Thus the demand estimates may have some downward bias.

Apart from quantifying the price to (possible) sales relationship, the study provides a tool to establish a suitable time profile of demand. Such a time profile could contribute to effective decision making and management of the introduction of this innovative technology into the seed and grain industry. It is also suggested that the time profile will be affected by effectiveness of technology in the field, and thus a base-case of adoption could be developed, against which the actual field performance can be compared on a continuous time frame.

In general, positive response to the system was influenced by the capacity for precision and high speed as well as by the removal of subjectivity. It was also possible to identify sectoral interest in specific attributes of the system, and this should help to design alternative configurations suitable for the different sectors. The viable price ratios between configurations were also estimated to provide guidance in the economics of system configuration.

APPENDIX
SURVEY QUESTIONNAIRE

Center for Agricultural and Rural Development
Department of Economics, Heady Hall, Iowa State University
Ames, Iowa. 50011

November 15, 1990

To prospective participants:

A DEMAND STUDY BY CARD

Ultrasonic and Video Imaging System for Grains, Seeds and Food Quality Assurance

The ISU Center for Advanced Technology Development (CATD) is sponsoring an applied research project to develop hi-tech equipment for grains, seeds and food quality assurance (QA). In support of this project, CARD (Center for Agricultural and Rural Development) is conducting a study to evaluate the industry demand for such QA equipment: specifically to identify the industry's needs and preferences in equipment for QA.

Interviewers from CARD will visit thirty firms in the grain, seed and food industry to gather the necessary information. During the visit, a 15-minute presentation demonstrating the proposed equipment will be made. This will be followed by a questionnaire session that we feel could be best answered by a management/professional in charge of QA. The questionnaire will take about 45 minutes to complete. Information gathered will include the volume of grain and seeds handled, testing procedures, costs of testing, reaction to computerized testing, and familiarity with and investments in computerization.

All the information gathered will be treated as strictly confidential, and will be used for the above purpose by ISU alone. The firm/personal information will be coded to conceal identity. Only CATD and CARD will have access to this information. The data analysis and reports will not identify either the firm/institution or the respondent.

Participation in the survey is purely voluntary.

This effort will help guide future research to suit your needs.

We appreciate your helping us to help you.

John W. Helmuth
Principal Investigator

Premakumar
Economist

Telephone: Off. (515)-294-0470 Telex : 283359 IASU UR Fax: (515)-294-6336

COVER SHEET

REF:

Survey for the study

Demand for grain, seed and food Quality Assurance System

This cover sheet will be detached from the main questionnaire at the completion of the survey. Information contained herein will be linked to the main survey only by the Reference Number to conceal identity of the responding institution as well as individuals. All such identifying information will be treated as strictly confidential. Responding to this survey is purely voluntary.

A1: Company/Institution		A4: Postal address	
A2: Telephone	A3: County	A5: City	A6: ZIP

A7: Name of Respondent	A8: Title	A9: Telephone
A10: Name of Co-Respondent	A11: Title	A12: Telephone
A13: Name of Co-Respondent	A14: Title	A15: Telephone

Other branches of company which may be contacted for additional information

A16: Name	A17: Contact person	A18: Title	A19: Tel.	A20: City	A21: Comments
A22: Name	A23: Contact person	A24: Title	A25: Tel.	A26: City	A27: Comments
A28: Name	A29: Contact person	A30: Title	A31: Tel.	A32: City	A33: Comments

A34: ANY OTHER COMMENTS

B1: Ref#
B2: Date:

QUESTIONNAIRE

Survey for the study

Demand for grain, seed and food Quality Assurance System

The information collected in this questionnaire will be used by CARD and the sponsors to study the market demand for the Ultrasonic and Video Imaging Quality Assurance System developed at the Seed Science Center at Iowa State University

B3: Responding office is:
[S] Single-branch business. [M] Main/Head office of multi-branch business. [B] Branch office of multi-branch business

B4: Code category of the local operation (P=Primary, S=Secondary)

Grain/seed grower		Grain/seed conditioner		End-user (mill/crusher)	
Grain/seed seller		Grader (stores/elevator)		Testing lab/Certifier	
Research Laboratory		Plant introduction facility		Other:________	
Other:________		Other:________		Other:________	

B5: If answer to B3 is M or B, Code category of the branch operations (P=Primary, S=Secondary)

Grain/seed grower		Grain/seed conditioner		End-user (mill/crusher)	
Grain/seed seller		Grader (stores/elevator)		Testing lab/Certifier	
Research Laboratory		Plant introduction facility		Other:________	
Other:________		Other:________		Other:________	

The rest of the Questionnaire relates to information pertaining to the local operation only

Total volume handled in:		1989		1990 (projected for full year)
Soybeans	B6:		B7:	
Corn	B8:		B9:	
Edible beans	B10:		B11:	
Other grains	B12:		B13:	
Others(Sp.)	B14:		B15:	

Any QA/seed testing done by outside laboratories:
(Code for tests: MT-Moisture, GM-Germination, DS-Disease, PU-Purity, WD-Weeds. Specify others)

Commodity	For what tests?	To whom?	Cost
B16:	B17:	B18:	B19:
B20:	B21:	B22:	B23:
B24:	B25:	B26:	B27:

Please list the nearest three QA or seed testing laboratories.

B50: Lab#1	B51: Lab#2	B52: Lab#3

	1989	1990
B60: Annual cost of QA/seed-testing (estimated)		
B61: As % of total operating cost of operation		

Computer facilities at location

Main frame [Y] [N]	Mini Computer [Y] [N]	PC's [0] [1-5] [5-10] [10-25] [> 25]	Are PC's Networked? [Y] [N]

Total staff at site	Staff trained in Computer: End users	Power users	Maintanance	Computer related investments ($)	1989	1990
				Hardware		
				Software		

List commonly used software (name the data base, spread sheet, statistical, word processing etc. packages):

______ ______ ______

______ ______ ______

Standard Sampling Procedure

SOYBEAN

Field sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

In transport - Truck sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - Before processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - After processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

CORN

Field sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

In transport - Truck sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - Before processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - After processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Other: ______

Field sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

In transport - Truck sampling

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - Before processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

Laboratory sampling - After processing

Define "Lot":
No. of lots in 1989: ______ 1990: ______
Samples per lot: ______ Sample size: ______
Describe usage/allocation of a standard sample:

ANY OTHER REMARKS RE. STANDARD SAMPLING PROCEDURE:

SOYBEAN -- Test characteristics

Codes:

- E Essential / U Useful / N Not useful
- VA Visual appeal / UN Uniformity / VI Varietal identification / DI Disease identification / GM Indicate germination capacity / FL Federal seed law adherence / SL State seed law adherence / Others – Specify
- Y Yes / N No
- B Bulk / S Seed-by-seed
- D Destroyed / N Not destroyed
- M Manual / A Automated
- V Visual examination with no tools/instruments / HT Visual examination with hand-held tool / VM Visual examination with mechanical equipment / A Automated, with no manual examination / Others – Specify

	Code importance	Why?	Currently done?	If not, why?	How done?	Describe	If sampling procedure is different from standard (page 2), explain.
Foreign seeds	E U N		Y N		B S D N M A		
Noxious weeds	E U N		Y N		B S D N M A		
Other weeds	E U N		Y N		B S D N M A		
Size	E U N		Y N		B S D N M A		
Shape	E U N		Y N		B S D N M A		
Color	E U N		Y N		B S D N M A		
Full/Shriveled	E U N		Y N		B S D N M A		
Shinny/Dull	E U N		Y N		B S D N M A		
Texture	E U N		Y N		B S D N M A		
Damaged	E U N		Y N		B S D N M A		
Splits	E U N		Y N		B S D N M A		
Shape of hilum	E U N		Y N		B S D N M A		
Color of hilum	E U N		Y N		B S D N M A		
Opaqueness	E U N		Y N		B S D N M A		
Insect damage	E U N		Y N		B S D N M A		
Moldy/discolored	E U N		Y N		B S D N M A		
Bleeding hilum	E U N		Y N		B S D N M A		
Growth marks	E U N		Y N		B S D N M A		
Moisture	E U N		Y N		B S D N M A		
Hardness of coat	E U N		Y N		B S D N M A		
Breakage susceptibility	E U N		Y N		B S D N M A		
Heat damage	E U N		Y N		B S D N M A		
Protein content	E U N		Y N		B S D N M A		
Oil content	E U N		Y N		B S D N M A		
ANY OTHER CHARACTERISTICS:	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		

CORN -- Test characteristics

Codes:

- E Essential, U Useful, N Not useful
- VA Visual appeal, UN Uniformity, VI Varietal identification, DI Disease identification, GM Indicate germination capacity, FL Federal seed law adherence, SL State seed law adherence, Others - Specify
- Y Yes, N No
- B Bulk, S Seed-by-seed
- D Destroyed, N Not destroyed
- M Manual, A Automated
- V Visual examination with no tools/instruments, HT Visual examination with hand-held tool, VM Visual examination with mechanical equipment, A Automated, with no manual examination, Others - Specify

	Code importance	Why?	Currently done?	If not, why?	How done?	Describe	If sampling procedure is different from standard (page 2), explain.
Foreign seeds	E U N		Y N		B S D N M A		
Noxious weeds	E U N		Y N		B S D N M A		
Other weeds	E U N		Y N		B S D N M A		
Size	E U N		Y N		B S D N M A		
Shape	E U N		Y N		B S D N M A		
Color	E U N		Y N		B S D N M A		
Full/Shriveled	E U N		Y N		B S D N M A		
Shinny/Dull	E U N		Y N		B S D N M A		
Texture	E U N		Y N		B S D N M A		
Damaged	E U N		Y N		B S D N M A		
Opaqueness	E U N		Y N		B S D N M A		
Insect damage	E U N		Y N		B S D N M A		
Moldy/discolored	E U N		Y N		B S D N M A		
Moisture	E U N		Y N		B S D N M A		
Hardness of coat	E U N		Y N		B S D N M A		
Breakage susceptibility	E U N		Y N		B S D N M A		
Heat damage	E U N		Y N		B S D N M A		
Stress cracks	E U N		Y N		B S D N M A		
Protein content	E U N		Y N		B S D N M A		
Oil content	E U N		Y N		B S D N M A		
ANY OTHER CHARACTERISTICS:	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		

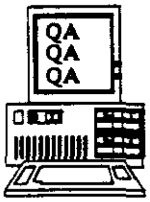
Commodity (specify) [ ] — **Test characteristics**

Codes:

- E Essential; U Useful; N Not useful
- VA Visual appeal; UN Uniformity; VI Varietal identification; DI Disease identification; GM Indicate germination capacity; FL Federal seed law adherence; SL State seed law adherence; Others - Specify
- Y Yes; N No
- B Bulk; S Seed-by-seed
- D Destroyed; N Not destroyed
- M Manual; A Automated
- V Visual examination with no tools/instruments; HT Visual examination with hand-held tool; VM Visual examination with mechanical equipment; A Automated, with no manual examination; Others - Specify

	Code importance	Why?	Currently done?	If not, why?	How done?	Describe	If sampling procedure is different from standard (page 2), explain.
Foreign seeds	E U N		Y N		B S D N M A		
Noxious weeds	E U N		Y N		B S D N M A		
Other weeds	E U N		Y N		B S D N M A		
Size	E U N		Y N		B S D N M A		
Shape	E U N		Y N		B S D N M A		
Color	E U N		Y N		B S D N M A		
Full/Shriveled	E U N		Y N		B S D N M A		
Shinny/Dull	E U N		Y N		B S D N M A		
Texture	E U N		Y N		B S D N M A		
Damaged	E U N		Y N		B S D N M A		
Opaqueness	E U N		Y N		B S D N M A		
Insect damage	E U N		Y N		B S D N M A		
Moldy/discolored	E U N		Y N		B S D N M A		
Moisture	E U N		Y N		B S D N M A		
Hardness of coat	E U N		Y N		B S D N M A		
Breakage susceptibility	E U N		Y N		B S D N M A		
Heat damage	E U N		Y N		B S D N M A		
Stress cracks	E U N		Y N		B S D N M A		
Protein content	E U N		Y N		B S D N M A		
Oil content	E U N		Y N		B S D N M A		
ANY OTHER CHARACTERISTICS:	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		
	E U N		Y N		B S D N M A		

QA System Standard Configurations



	Complete	Ultra-sound Sub-system	Imaging Sub-system	Chlorox Tester	Corn Hardness Tester	Breakage Tester	Sizing & Screen Selection
Computer	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transducer	Yes	Yes				Yes	
Digitizer	Yes	Yes				Yes	
Feeder	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Video Camera	Yes		Yes	Mono	Mono		Mono
FrameGrabber	Yes		Yes	Mono	Mono		Mono
Lighting	Yes		Yes	Yes	Yes		Yes
Printer	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Needed Software	Yes	Yes	Yes	Yes	Yes	Yes	Yes

System capabilities

	Complete	Ultra-sound Sub-system	Imaging Sub-system	Chlorox Tester	Corn Hardness Tester	Breakage Tester	Sizing & Screen Selection
1. Size	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Shape	Yes		Yes	Yes	Yes		Yes
3. Color	Yes		Yes				
4. Full/Shrivelled	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. Shinny/dull	Yes		Yes	Yes	Yes		Yes
6. Texture(smooth,etc)	Yes		Yes	Yes	Yes		Yes
7. Damage/chipped	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. Splits	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Shape of hilum	Yes		Yes	Yes	Yes		Yes
10. Color of hilum	Yes		Yes				
11. Bleeding hilum	Yes		Yes				
12. Opaqueness	Yes		Yes				
13. Insect damage	Partial	Partial	Partial	Partial	Partial	Partial	Partial
14. Moldy	Yes		Yes	Yes	Yes		Yes
15. Growth marks(Soybean)	Yes		Yes	Yes	Yes		Yes
16. Moisture	Yes	Yes				Yes	
17. Hardness of coat(Soybean)	Yes	Yes				Yes	
18. Hardness of seed	Yes	Yes				Yes	
19. Breakage suscep.	Yes	Yes	Partial	Partial	Partial	Yes	Partial
20. Stress cracks(Corn)	Yes		Yes	Yes	Yes		Yes
21. Heat damage	Yes		Yes	Yes	Yes		Yes
22. Protein content	May be	May be				May be	
23. Oil content	May be	May be				May be	
24. Ratio of s/h starch	Yes		Yes	Yes	Yes		Yes
25. Color of flour(corn)	Yes		Yes				

[shaded] Yes [Partial] Not completed [May be] Possible, by correlations [blank] No

Some of QA System Advantages

a. High speed
b. Reduced subjectivity (less human error)
c. Economical (labor saving)
d. Increased precision
e. Wide applications
f. Telecommunication capability
g. Simultaneous tests
h. Adaptability to suit specific environments
i. Reduced work space and tools
j. Less tedious
k. Automated testing and sorting
l. Available as Standard, Pre-configured options or custom made

Response to QA System

Rate the overall QA System: [E] Excellent [V] Very good [G] Good [S] Satisfactory [N] Not interested

List the features of MOST interest, and rate them.
Features are 1 to 25 or (a) to (l) above.
(C-Critical, V-Very useful, U-Useful)
1. ______ [C] [V] [U]
2. ______ [C] [V] [U]
3. ______ [C] [V] [U]
4. ______ [C] [V] [U]
5. ______ [C] [V] [U]

List the features of LEAST interest, and rate them.
Features are 1 to 25 or (a) to (l) above.
(U-Useful, N-Of no interest) — Any suggestions
1. ______ [U] [N] ____________
2. ______ [U] [N] ____________
3. ______ [U] [N] ____________
4. ______ [U] [N] ____________
5. ______ [U] [N] ____________

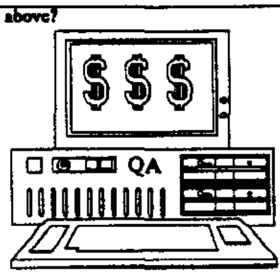
Any other features/options that will be of interest:
1.
2.
3.
4.

Rank the system configurations presented above, in order of preference (Rank 1 to 7, with 1 to denote most interest)
[ ] Complete system [ ] Ultra-sound SS [ ] Imaging SS [ ] Chlorox tester
[ ] Hardness tester [ ] Breakage tester [ ] Sizing system

What is your best guess on the price of the three configurations ranked 1 to 3 above?
(Two guesses, in order, to the closest thousand dollar)

Price in U.S. $

Choice	Guess 1	Guess 2
1. ____________		
2. ____________		
3. ____________		



Please use reverse side for any other comments or suggestions

ENDNOTES

1. This firm's responses were compared to the sample to ensure that there was no bias arising from including this "volunteer" in the random sample.

2. The U.S. dollar prices obtained in the survey, and reported in our submission to CATD, are confidential information. Thus, in this technical report, all information directly related to absolute price levels is either omitted or is masked.

3. The actual price level is not reported to retain the confidentiality of data. From the data plot in Figures 5, 6, and 7 it can be seen that a linear fit is better limited to a lower subset of the data.

4. Effectiveness (E) is an index assumed to range from zero to 100 percent. A variable Z was constructed as an exponential function of effectiveness.

$$Z = x\left[e^{e^{-y(E-50)/50}} - 1\right]$$

   Formulated thus, Z decreases exponentially with E, and when E equals 50, Z is zero. Z is positive for $E < 50$, and negative for $E > 50$. The parameters x and y can be adjusted to suit specific assumptions for the extreme values of Z (for E equals 0 and 100). For the projections in this study, Z was assumed to be .8 and −.15 at zero and 100 percent effectiveness, respectively. Time response to effectiveness (in percent) is equated to Z*100, while quantity response is equated to (1−Z)*100, to achieve the results discussed.

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